TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Holston River Watershed

(HUC 06010104)

Grainger, Hamblen, Hawkins, Jefferson, Knox, Sevier,

Sullivan and Union Counties, Tennessee

FINAL

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DEPARTMENT OF ENVIRONMENT & CONSERVATION

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
CS	Collection System
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Holston River Watershed (HUC 06010104)

Impaired Waterbody Information

State: Tennessee
Counties: Grainger, Hamblen, Hawkins, Jefferson, Knox, and Union
Watershed: Holston River (HUC 06010104)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN06010104001 – 0500	ROSEBERRY CREEK	20.0
TN06010104001 – 0800	LOST CREEK	26.8
TN06010104001 – 0900	BEAVER CREEK	21.0
TN06010104001 – 1400	SWANPOND CREEK	16.3
TN06010104004T – 1150	CANEY CREEK	16.8
TN06010104004T – 1200	CROCKETT CREEK	5.3
TN06010104004T – 2100	TURKEY CREEK	8.0
TN06010104004T – 2400	MOSSY CREEK	9.1
TN06010104011 – 0100	SINKING CREEK	2.7
TN06010104011 – 0200	FORGEY CREEK	3.6
TN06010104011 – 0300	SURGOINSVILLE CREEK	7.0
TN06010104011 – 0400	STONEY POINT CREEK	13.1
TN06010104011 – 0500	BRADLEY CREEK	9.2
TN06010104011 – 0510	RENFROE CREEK	12.5
TN06010104011 – 0700	HORD CREEK	8.9
TN06010104011 – 0800	ALEXANDER CREEK	1.0
TN06010104011 – 0850	ALEXANDER CREEK	12.5
TN06010104011 – 0900	SMITH CREEK	4.6
TN06010104011 – 1600	HUNT CREEK	7.7
TN06010104015 – 0300	STANLEY CREEK	7.7
TN06010104018 – 1000	RICHLAND CREEK	26.7
TN06010104019 – 0100	LITTLE FLAT CREEK	30.3
TN06010104019 – 2000	FLAT CREEK	2.8

Designated Uses:

The designated use classifications for waterbodies in the Holston River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2007 Version* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, Exceptional Tennessee Water or ONRW (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

For further information on Tennessee's general water quality standards, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

TMDL Scope:

Waterbodies identified on the Final 2008 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Holston River watershed were developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Water and 941 CFU/100 mL maximum water quality criterion for all other waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow zone represented by these existing loads. Load duration curves were also used to determine percent load reduction goals to meet the target maximum loading for E. coli. When sufficient data were available, load reductions were also determined based on geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

For each impaired waterbody, critical conditions were determined by evaluating the percent load reduction goals, for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal of the greatest magnitude corresponds with the critical flow zone.

Seasonal Variation:

The 10-year period used for LSPC model simulation period for development of load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0101 (DA)	Alexander Creek	TN06010104011 – 0850	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.61 \times 10^{6} \times Q$	$3.61 \times 10^{6} \times Q$
0101 (DA)	Hord Creek	TN06010104011 – 0700	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.61 \times 10^{6} \times Q$	$5.61 \times 10^{6} \times Q$
0101 (DA)	Smith Creek	TN06010104011 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$1.09 \times 10^{7} \times Q$	$1.09 \times 10^{7} \times Q$
0102 (DA)	Bradley Creek	TN06010104011 – 0500	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.84 \times 10^{6} \times Q$	$2.84 \times 10^{6} \times Q$
0102 (DA)	Forgey Creek	TN06010104011 – 0200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	1.50×10^{9}	0	NA	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$
0102 (DA)	Hunt Creek	TN06010104011 – 1600	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$8.90 \times 10^{6} \times Q$	$8.90 \times 10^{6} \times Q$
0102 (DA)	Renfroe Creek	TN06010104011 – 0510	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.48 \times 10^{6} \times Q$	$5.48 \times 10^{6} \times Q$
0102 (DA)	Sinking Creek	TN06010104011 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.62 \times 10^{7} \times Q$	$1.62 \times 10^{7} \times Q$
0102 (DA)	Stoney Point Creek	TN06010104011 – 0400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.42 \times 10^{6} \times Q$	$5.42 \times 10^{6} \times Q$
0102 (DA)	Surgoinsville Creek	TN06010104011 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$7.33 \times 10^{6} \times Q$	$7.33 \times 10^{6} \times Q$
0103 (DA)	Stanley Creek	TN06010104015 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$4.82 \times 10^{6} \times Q$	$4.82 \times 10^{6} \times Q$
0201 (DA)	Crockett Creek	TN06010104004T – 1200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$7.01 \times 10^{6} \times Q$	$7.01 \times 10^{6} \times Q$
0204 (DA)	Caney Creek	TN06010104004T – 1150	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.27 \times 10^{6} \times Q$	$2.27 \times 10^{6} \times Q$
0207 (DA)	Turkey Creek	TN06010104004T – 2100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$3.97 \times 10^{9} \times Q_2$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$
0210 (DA)	Mossy Creek	TN06010104004T – 2400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.13 \times 10^{6} \times Q$	$3.13 \times 10^{6} \times Q$
0302 (DA)	Beaver Creek	TN06010104001 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.59 \times 10^{6} \times Q$	$1.59 \times 10^{6} \times Q$
0302 (DA)	Lost Creek	TN06010104001 – 0800	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.86 \times 10^{6} \times Q$	$1.86 \times 10^{6} \times Q$

Summary (cont'd). TMDLs, WLAs, & LAs for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0303	Richland Creek	TN06010104018 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	7.40×10^{9}	0	NA	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$
0304 (DA)	Swanpond Creek	TN06010104001 – 1400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.21 \times 10^{6} \times Q$	$3.21 \times 10^{6} \times Q$
0305 (DA)	Flat Creek	TN06010104019 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.47 \times 10^{6} \times Q$	$1.47 \times 10^{6} \times Q$
0305 (DA)	Little Flat Creek	TN06010104019 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	$1.66 \times 10^{6} \times Q$	$1.66 \times 10^{6} \times Q$
0306	Roseberry Creek	TN06010104001 – 0500	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	$2.45 \times 10^{6} \times Q$	$2.45 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Industrial Point Source
CS = Collection Systems

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.

b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.

PROPOSED E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL) HOLSTON RIVER WATERSHED (HUC 06010104)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Holston River Watershed, identified on the Final 2008 303(d) list as not supporting designated uses due to E. coli. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only.

3.0 WATERSHED DESCRIPTION

The Holston River Watershed (HUC 06010104) is located in the northern portion of Eastern Tennessee (Figure 1), primarily in Grainger, Hamblen, Hawkins, Jefferson, and Knox Counties. The Holston River Watershed lies within one Level III ecoregion (Ridge and Valley) and contains four Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the solids vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.
- **The Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn , tobacco, and garden crops are grown on the foot slopes and bottomland.

- **The Southern Sandstone Ridges (67h)** ecoregion encompasses the major sandstone ridges, but these ridges also have areas of shale and siltstone. The steep, forested chemistry of streams flowing down the ridges can vary greatly depending on the geologic material. The higher elevation ridges are in the north, including Wallen Ridge, Powell Mountain, Clinch Mountain, and Bays Mountain. White Oak Mountain in the south has some sandstone on the west side, but abundant shale and limestone as well. Grindstone Mountain, capped by the Gizzard Group sandstone, is the only remnant of Pennsylvanian-age strata in the Ridge and Valley of Tennessee.

- **The Southern Dissected Ridges and Knobs (67i)** contain more crenulated, broken, or hummocky ridges, compared to smoother, more sharply pointed sandstone ridges. Although shale is common, there is a mixture and interbedding of geologic materials. The ridges on the east side of Tennessee's Ridge and Valley tend to be associated with the Ordovician-age Sevier shale, Athens shale, and Holston and Lenoir limestones. These can include calcareous shale, limestone, siltstone, sandstone, and conglomerate. In the central and western part of the ecoregion, the shale ridges are associated with the Cambrian-age Rome Formation: shale and siltstone with beds of sandstone. Chestnut oak forests and pine forests are typical for the higher elevations of the ridges, with areas of white oak, mixed mesophytic forest, and tulip poplar on the lower slopes, knobs, and draws.

The Holston River Watershed, located in Grainger, Hamblen, Hawkins, Jefferson, Knox, Sevier, Sullivan, and Union Counties, Tennessee, has a drainage area of approximately 1,000 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Holston River Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use in the Holston River Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Holston River Watershed is forest (55.5%) followed by pasture (25.4%). Urban areas represent approximately 14.2% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Holston River Watershed are presented in Appendix A.

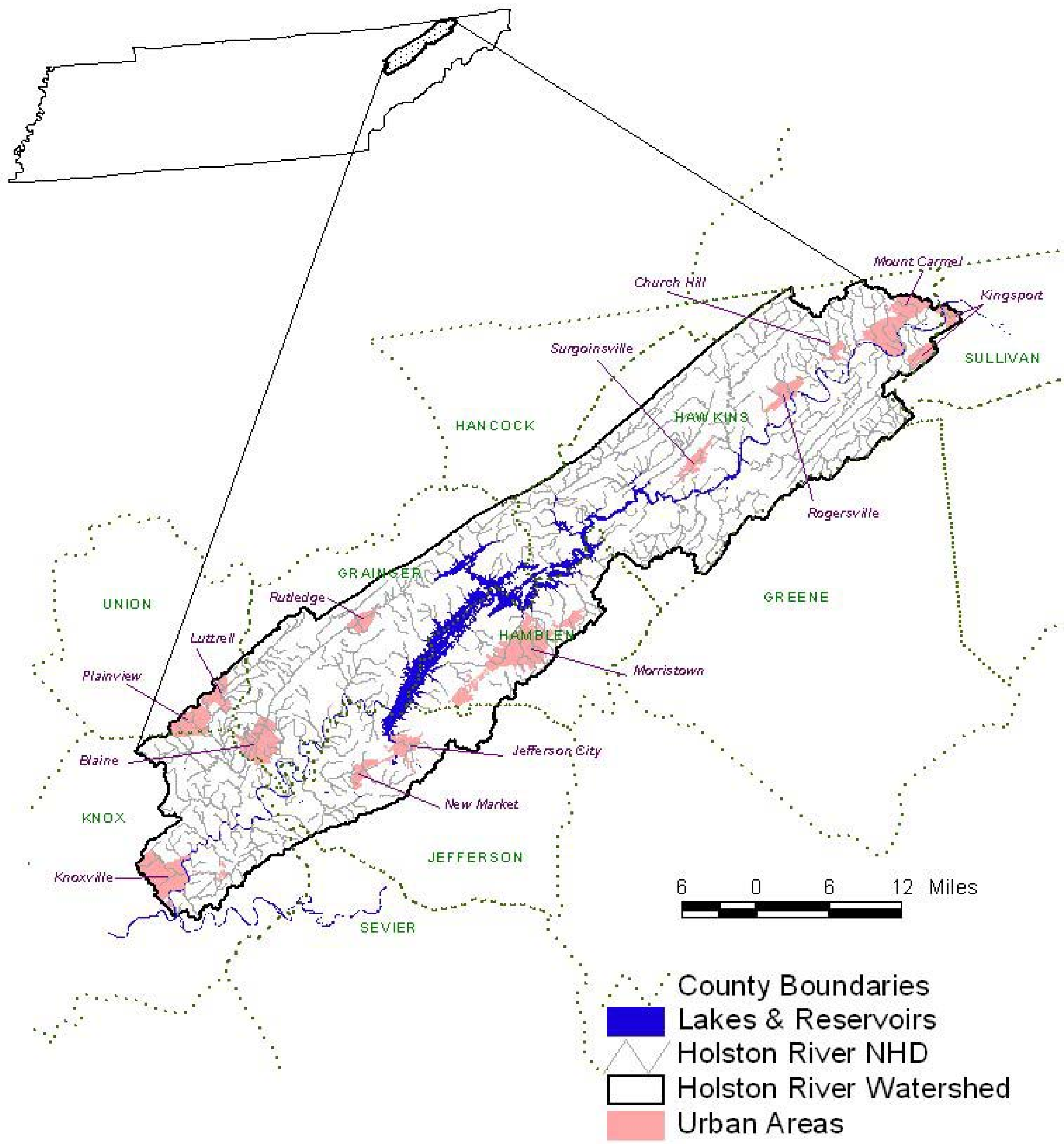

Figure 1. Location of the Holston River Watershed.

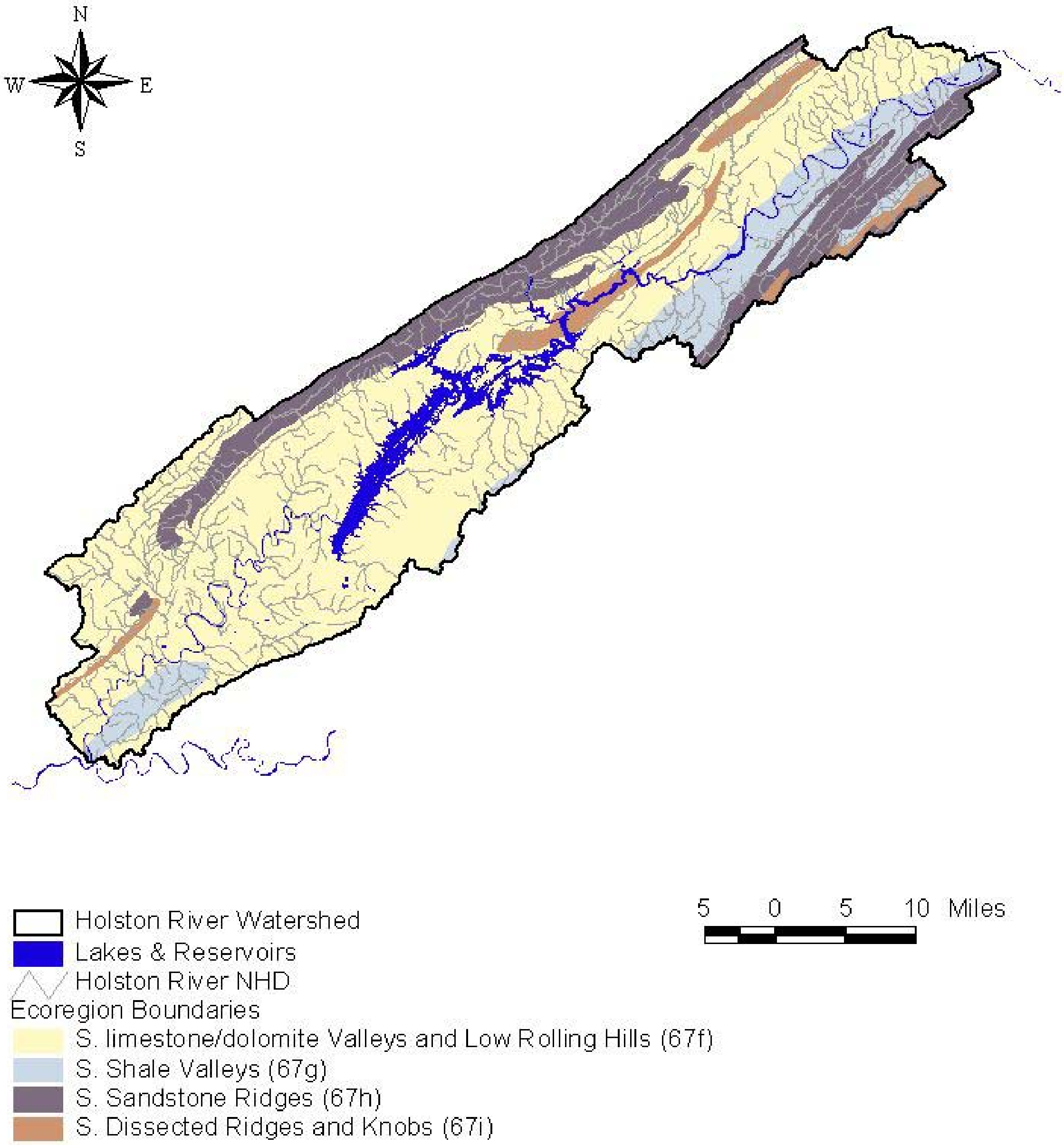

Figure 2. Level IV Ecoregions in the Holston River Watershed.

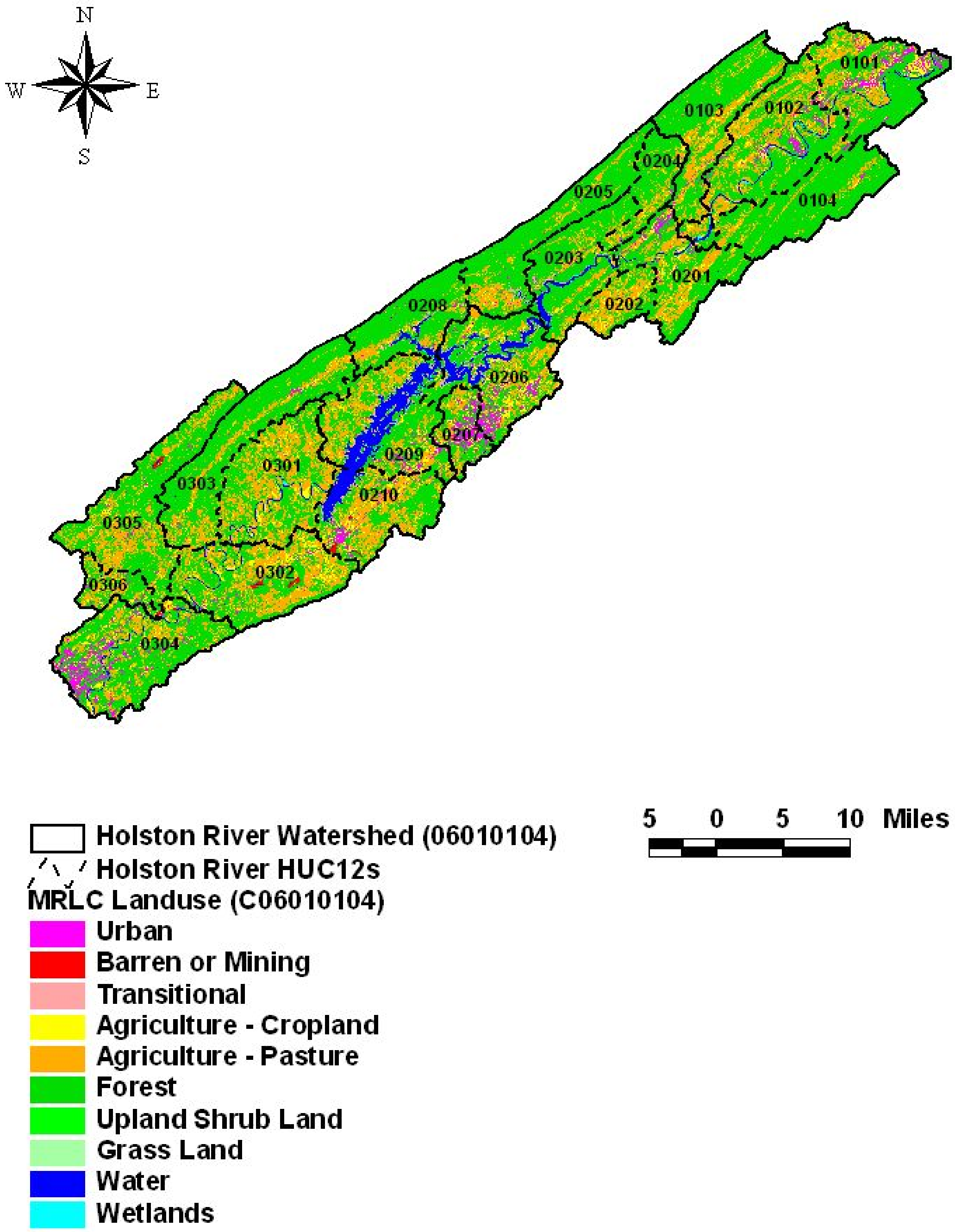

Figure 3. Land Use Characteristics of the Holston River Watershed.

Table 1. MRLC Land Use Distribution – Holston River Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	205	0.0
Deciduous Forest	193,138	30.2
Emergent Herbaceous Wetlands	717	0.1
Evergreen Forest	77,503	12.1
High Intensity Commercial/Industrial/ Transportation	7,524	1.2
High Intensity Residential	1,581	0.2
Low Intensity Residential	11,532	1.8
Mixed Forest	123,900	19.3
Open Water	22,583	3.5
Other Grasses (Urban/recreational)	8,933	1.4
Pasture/Hay	162,894	25.4
Quarries/Strip Mines/ Gravel Pits	1,080	0.2
Row Crops	24,213	3.8
Transitional	3,986	0.6
Woody Wetlands	553	0.1
Total	**640,343**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2008 303(d) list (TDEC, 2008), http://state.tn.us/environment/wpc/publications/303d2008.pdf, was approved by the U.S. Environmental Protection Agency (EPA), Region IV in June of 2008. This list identified portions of 22 waterbodies in the Holston River Watershed as not fully supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Alexander Creek, Bradley Creek, Mossy Creek, and Turkey Creek are also designated for drinking water supply and/or industrial water supply uses. Portions of Alexander Creek and Mossy Creek are designated as trout streams.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Holston River waterbodies include fish & aquatic life, recreation, irrigation, and livestock watering & wildlife. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2007 Version* (TDEC, 2007).

As of March 28, 2008, none of the impaired waterbodies in the Holston River Watershed have been classified as lakes, reservoirs, or Exceptional Tennessee Waters.

For further information concerning Tennessee's general water quality criteria and Tennessee's Antidegradation Statement, including the definition of Exceptional Tennessee Waters, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf .

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development.

Table 2 Final 2008 303(d) List for E. coli Impaired Waterbodies – Holston River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010104001 – 0500	ROSEBERRY CREEK	20.0	Escherichia coli	Pasture Grazing Septic Tanks
TN06010104001 – 0800	LOST CREEK	26.8	Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing Septic Tanks
TN06010104001 – 0900	BEAVER CREEK	21.0	Escherichia coli	Pasture Grazing
TN06010104001 – 1400	SWANPOND CREEK	16.3	Loss of biological integrity due to siltation Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Land Development Channelization Discharges from MS4 Area
TN06010104004T – 1150	CANEY CREEK	16.8	Escherichia coli	Pasture Grazing
TN06010104004T – 1200	CROCKETT CREEK	5.3	Loss of biological integrity due to siltation Escherichia coli	Land Development Discharges from MS4 Area
TN06010104004T – 2100	TURKEY CREEK	8.0	Loss of biological integrity due to siltation Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Collection System Failure Discharges from MS4 Area
TN06010104004T – 2400	MOSSY CREEK	9.1	Zinc Loss of biological integrity due to siltation Escherichia coli	Collection System Failure Discharges from MS4 Area Resource Extraction
TN06010104011 – 0100	SINKING CREEK	2.7	Escherichia coli	Pasture Grazing
TN06010104011 – 0200	FORGEY CREEK	3.6	Escherichia coli	Pasture Grazing
TN06010104011 – 0300	SURGOINSVILLE CREEK	7.0	Escherichia coli	Pasture Grazing Septic Tanks

Table 2 (cont'd) Final 2008 303(d) List for E. coli Impaired Waterbodies – Holston River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010104011 – 0400	STONEY POINT CREEK	13.1	Escherichia coli	Pasture Grazing
TN06010104011 – 0500	BRADLEY CREEK	9.2	Escherichia coli	Livestock in Stream
TN06010104011 – 0510	RENFROE CREEK	12.5	Escherichia coli	Livestock in Stream
TN06010104011 – 0700	HORD CREEK	8.9	Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010104011 – 0800	ALEXANDER CREEK	1.0	Loss of biological integrity due to undetermined cause Escherichia coli	Discharges from MS4 Area
TN06010104011 – 0850	ALEXANDER CREEK	12.5	Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010104011 – 0900	SMITH CREEK	4.6	Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Pasture Grazing Land Development
TN06010104011 – 1600	HUNT CREEK	7.7	Escherichia coli	Livestock in Stream
TN06010104015 – 0300	STANLEY CREEK	7.7	Escherichia coli	Pasture Grazing
TN06010104018 – 1000	RICHLAND CREEK	26.7	Escherichia coli	Pasture Grazing
TN06010104019 – 0100	LITTLE FLAT CREEK	30.3	Escherichia coli	Confined Animal Feeding Operations (NPS)
TN06010104019 – 2000	FLAT CREEK	2.8	Loss of biological integrity due to siltation Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Hydromodification Dam Construction Pasture Grazing Collection System Failure

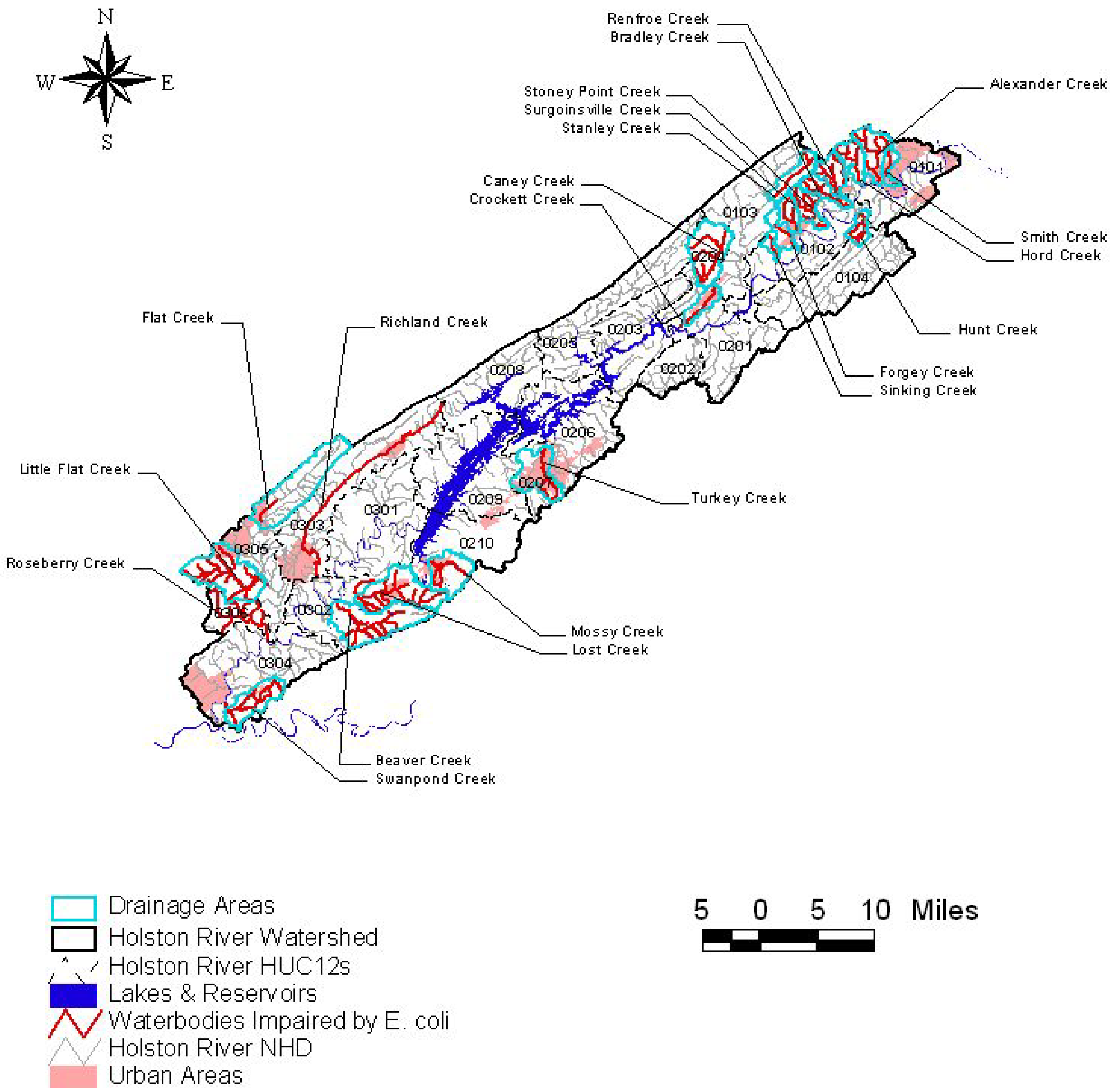

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2008 303(d) List).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are multiple water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Holston River Watershed:

- HUC-12 06010104_0101:
  - ALEXA000.6HS – Alexander Creek, at First Utility District Water Plant
  - ALEXA001.4HS – Alexander Creek, Lane Street at park
  - HORD000.2HS – Hord Creek, at Rice Mill, just off US Hwy 11W
  - SMITH000.9HS – Smith Creek, below golf course, at Silver Lake Rd.
- HUC-12 06010104_0102:
  - BRADL000.1HS – Bradley Creek, east of Greenland Rd., d/s AFG plant
  - BRADL001.4HS – Bradley Creek, d/s US Hwy 11W, u/s Burlington Rd.
  - BRADL002.8HS – Bradley Creek, private drive south of Cross Valley Rd.
  - FORGE000.8HS – Forgey Creek, at Williams Rd.
  - HUNT001.0HS – Hunt Creek, bridge on Christian Bend Rd.
  - RENFR000.2HS – Renfroe Creek, at US Hwy 11W
  - RENFR001.0HS – Renfroe Creek, east of Fudge Chapel Rd.
  - SINKI001.1HS – Sinking Creek, at Old State Rd.
  - SPOIN000.1HS – Stoney Point Creek, at Phipps Bend
  - SURGO000.1HS – Surgoinsville Creek, mouth, at Millers Bluff Rd.
- HUC-12 06010104_0103:
  - STANL000.1HS – Stanley Creek, at Housewright Rd.
- HUC-12 06010104_0201:
  - CROCK001.8HS – Crockett Creek, at Rogersville POTW, at Beaver Rd.
- HUC-12 06010104_0204:
  - CANEY009.1HS – Caney Creek, Hwy 70 at Striggersville
- HUC-12 06010104_0207:
  - TURKE001.7HA – Turkey Creek, at Fairview Rd. bridge
- HUC-12 06010104_0210:
  - MOSSY001.3JE – Mossy Creek, at Russell Ave. bridge in Jefferson City
- HUC-12 06010104_0302:
  - BEAVE000.4JE – Beaver Creek, at Beaver Creek Rd.
  - LOST000.7JE – Lost Creek, at Day Rd. bridge
  - LOST004.2JE – Lost Creek, at Hwy 11E bridge, at New Market
  - LOST008.6JE – Lost Creek, at Sweet Williams Lane bridge

- HUC-12 06010104_0303:
    - RICHL000.8GR – Richland Creek, at Nancy Ferry Rd. bridge
    - RICHL014.4GR – Richland Creek, at Owl Hole Rd. bridge
- HUC-12 06010104_0304:
    - SWANP000.8KN – Swanpond Creek, bridge on Holston River Rd.
- HUC-12 06010104_0305:
    - FLAT015.3UN – Flat Creek, at Hwy 61 bridge, d/s of Luttrell
    - LFLAT000.3KN – Little Flat Creek, at Idumea Rd. bridge
- HUC-12 06010104_0306:
    - ROSEB000.6KN – Roseberry Creek, at Mascot Pike bridge

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 941 CFU/100 mL maximum E. coli standard at many monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3. Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean was calculated.

Table 3 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
ALEXA000.6HS	2000 – 2005	16	26	519	2,419	2
ALEXA001.4HS	2000 – 2005	16	64	957	2,419	6
BEAVE000.4JE	2004	10	276	829	1,732	4
BRADL000.1HS	2004 – 2005	12	310	6,624	57,940	8
BRADL001.4HS	2000 – 2005	16	108	2,129	9,870	7
BRADL002.8HS	2004-2005	12	740	3,732	12,230	10
CANEY009.1HS	2000 – 2005	16	236	870	3,680	4
CROCK001.8HS	2000 – 2005	16	44	822	5,290	3
FLAT015.3UN	2004	12	135	502	1,046	1
FORGE000.8HS	2000 – 2005	16	109	1,127	5,880	5
HORD000.2HS	2000 – 2005	15	50	412	1,300	1
HUNT001.0HS	2000 – 2005	17	1	1,151	9,600	6

Table 3 (cont'd) Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
LFLAT000.3KN	2004	12	272	776	2,419	2
LOST000.7JE	2004	10	400	2,130	2,419	9
LOST004.2JE	2004	10	326	1,069	2,419	3
LOST008.6JE	2004	10	32	644	1,203	2
MOSSY001.3JE	2004	10	73	775	2,419	3
RENFR000.2HS	2000 – 2005	16	35	3,153	38,730	6
RENFR001.0HS	2004 – 2005	12	172	2,636	22,820	4
RICHL000.8GR	2004	10	157	535	1,203	2
RICHL014.4GR	2004	10	190	411	816	0
ROSEB000.6KN	2004	10	276	518	1,300	1
SINKI001.1HS	2000 – 2005	16	47	1,164	2,419.2	8
SMITH000.9HS	2000 – 2005	15	14	480	2,419	3
SPOIN000.1HS	2000 – 2005	16	53	730	2,419	3
STANL000.1HS	2000 – 2005	15	98	555	2,419	2
SURGO000.1HS	2000 – 2005	16	84	665	2,419	3
SWANP000.8KN	2004	11	119	308	548	0
TURKE001.7HA	2004	10	548	1,889	2,419	9

Several of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2419. For the purpose of calculating summary data statistics, TMDLs, Waste Load Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2419. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol. See Section 9.4.

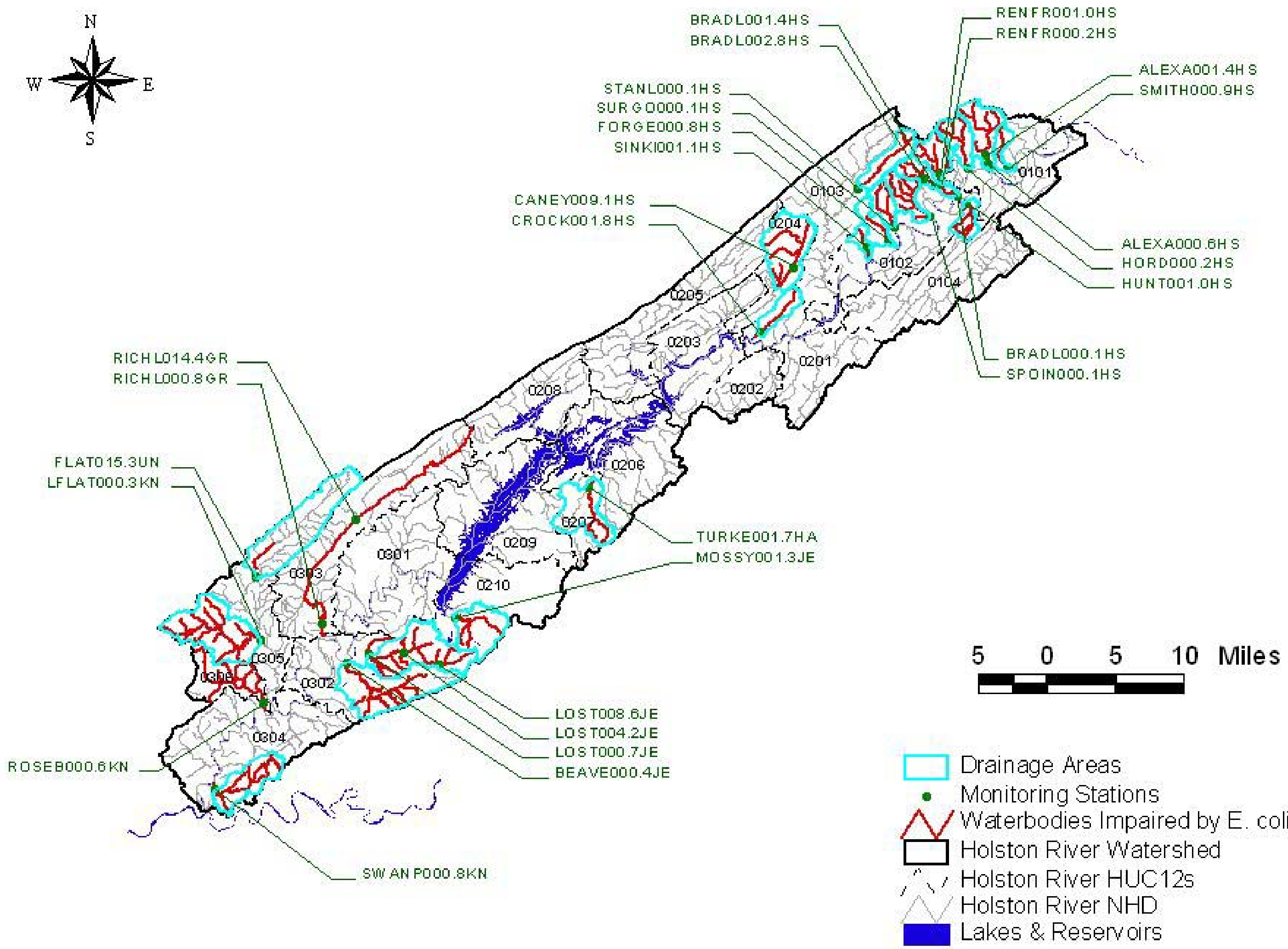

Figure 5. Water Quality Monitoring Stations in the Holston River Watershed

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm), a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program (http://cfpub1.epa.gov/npdes/index.cfm) regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal (http://cfpub1.epa.gov/npdes/home.cfm?program_id=13) and industrial (http://cfpub1.epa.gov/npdes/home.dfm?program_id=14) wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6); and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs) (http://cfpub1.epa.gov/npdes/home.cfm?program_id=7)). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 21 WWTFs in the Holston River Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. Eleven of these facilities are located in or near impaired subwatersheds or drainage areas (see Table 4 & Figure 6). However, only three of the facilities discharge to impaired waterbodies. The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems (LCSs) and sanitary sewer overflows (SSOs).

> *Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.*

Table 4 NPDES Permitted WWTFs with Collection Systems Serving Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0021105	Rutledge STP	0.2	Richland Creek @RM18.6
TN0055468	Surgoinsville Middle & Elementary Schools	0.042	Forgey Creek @RM1.4
TN0074497	Joppa Elementary School	0.00786	Richland Creek @RM12.5
TN0020672	Rogersville STP	1.3	Holston River @RM99.7 (Cherokee Reservoir)
TN0021199	Jefferson City STP	1.0	Mossy Creek Embayment of Holston River
TN0021253	Church Hill STP	2.5	Holston River @RM136.5
TN0021822	KUB – Loves Creek STP	10.3	Holston River @RM5.0
TN0023507	Morristown STP	15.2	Holston River @RM75
TN0061743	KUB – East Bridge STP	1.33	Holston River @RM14.2
TN0062057	Mount Carmel STP	0.472	Holston River @RM137.5
TN0064149	Luttrell STP	0.2	Flat Creek @RM13.9

7.1.2 NPDES Regulated Municipal and Industrial Stormwater

7.1.2.1 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase1) requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, Knoxville is the only MS4 of this size in the Holston River Watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase2). A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf) (TDEC, 2003). Five counties (Hamblen, Hawkins, Knox, Sevier, and Sullivan) and four municipalities (Church Hill, Kingsport, Morristown, and Mount Carmel) are covered under Phase II of the NPDES Storm Water Program.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State roads and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas. TDOT's individual MS4 permit may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website: http://state.tn.us/environment/wpc/stormh2o/TNS077585.pdf .

For information regarding storm water permitting in Tennessee, see the TDEC website:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.2.2 NPDES Regulated Industrial Stormwater

Industrial facilities can also be point sources of E. coli. Most stormwater discharges from industrial facilities are covered under the Tennessee Stormwater Multi-Section General Permit (TMSP). However, there are two facilities in the Holston River Watershed covered under individual permits that require monthly monitoring of coliform levels. One of these facilities discharges to an impaired waterbody.

Koch Foods LLC (TN0067989) is located in Hamblen County and discharges to the west fork of Turkey Creek. This facility has a long history of bacteriological problems with their stormwater runoff. However, there has been considerable improvement since Koch Foods took this facility over from the previous company. The facility treats the first half hour of stormwater by pumping it to a pretreatment system for treatment and then discharging it to the city sewer system. They also clean the yard by sweeping and cleaning any spill before rain carries it to the retention pond. They are building a roof over their truck delivery area. This area is for delivering live chickens before slaughtering. They are also going to build a baffle in the retention pond in order to avoid any flow short circuiting.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* (http://state.tn.us/environment/wpc/programs/cafo/CAFO_GP_04.pdf), while larger, Class I CAFOs are required to obtain an individual NPDES permit.

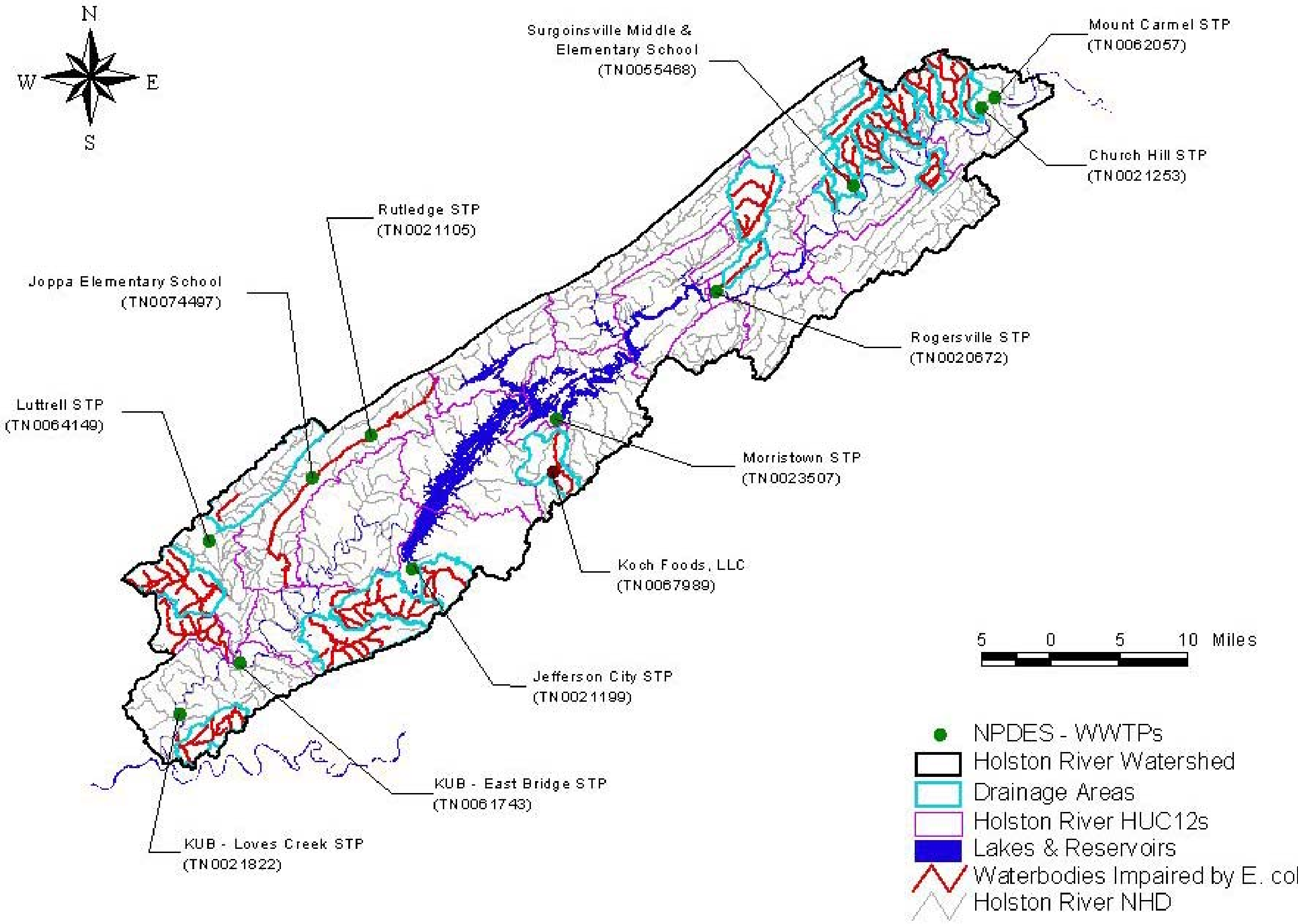

Figure 6. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Holston River Watershed.

As of July 1, 2008, there are no Class I CAFOs with individual permits and two Class II CAFOs with coverage under the general NPDES permit located in impaired subwatersheds of the Holston River Watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2008 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture (http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm). Livestock data for counties located within the Holston River watershed are summarized in Table 5. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 5 Livestock Distribution in the Holston River Watershed

County	Livestock Population (2002 Census of Agriculture)						
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Horse
			Layers	Broilers			
Grainger	13,334	884	981	229	135	361	1,351
Hamblen	9,054	857	430	575,651	956	127	840
Hawkins	20,337	443	1,658	280,310	296	354	2,259
Jefferson	18,634	1,546	1,086	783,172	293	799	2,080
Knox	12,760	611	3,819	1,003	193	414	3,111
Sevier	9,646	11	1,297	D	57	77	2,033
Sullivan	13,632	720	1,628	154	186	381	2,738
Union	5,928	66	828	90	46	27	798

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.3 Failing Septic Systems

Some of the coliform loading in the Holston River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Holston River watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 6 Estimated Population on Septic Systems in the Holston River Watershed

County	Total Population (2000 Census)	Population on Septic Systems
Grainger	20,659	16,464
Hamblen	58,128	50,138
Hawkins	53,563	30,512
Jefferson	44,294	27,707
Knox	382,032	174,240
Sevier	71,170	51,043
Sullivan	153,048	114,917
Union	17,808	13,303

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. Urban land use area in impaired subwatersheds in the Holston River Watershed ranges from 0.2% to 29.0%. Land use for the Holston River impaired drainage areas is summarized in Figures 7 thru 12 and tabulated in Appendix A.

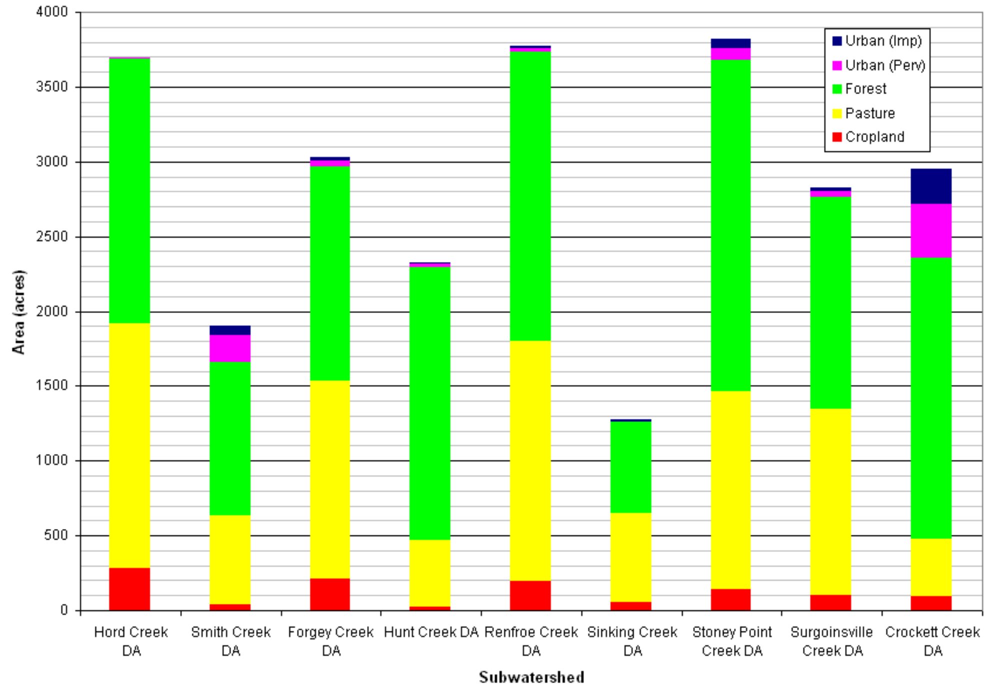

Figure 7. Land Use Area of Holston River E. coli-Impaired Subwatersheds – Drainage Areas Less Than 4,000 Acres

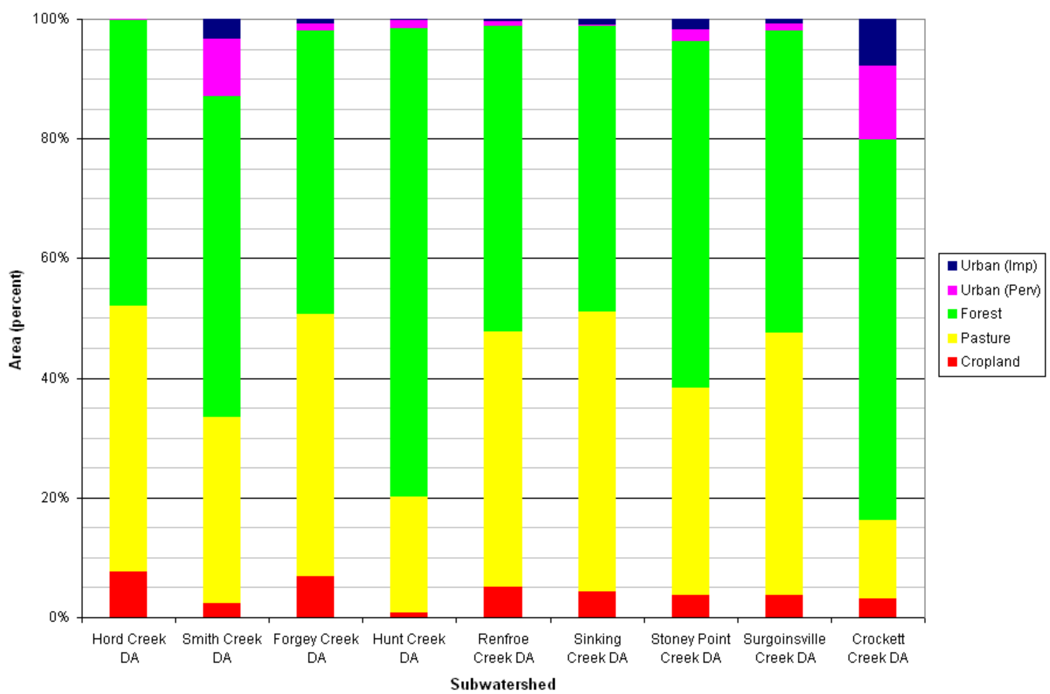

Figure 8. Land Use Percent of the Holston River E. coli-Impaired Subwatersheds – Drainage Areas Less Than 4,000 Acres

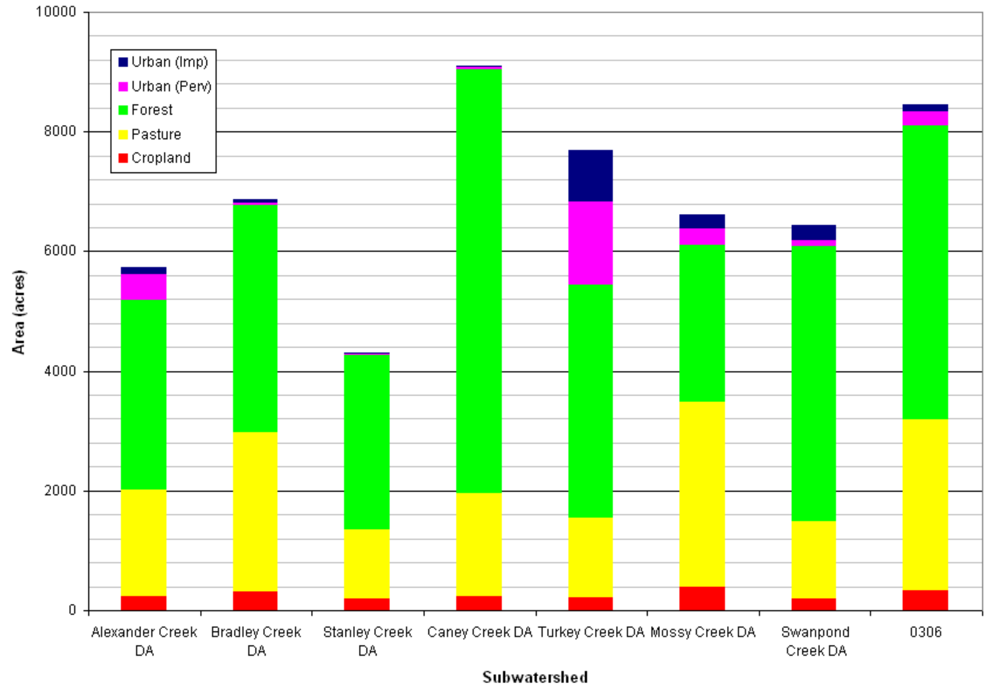

Figure 9. Land Use Area of Holston River E. coli-Impaired Subwatersheds – Drainage Areas Between 4,000 and 10,000 Acres

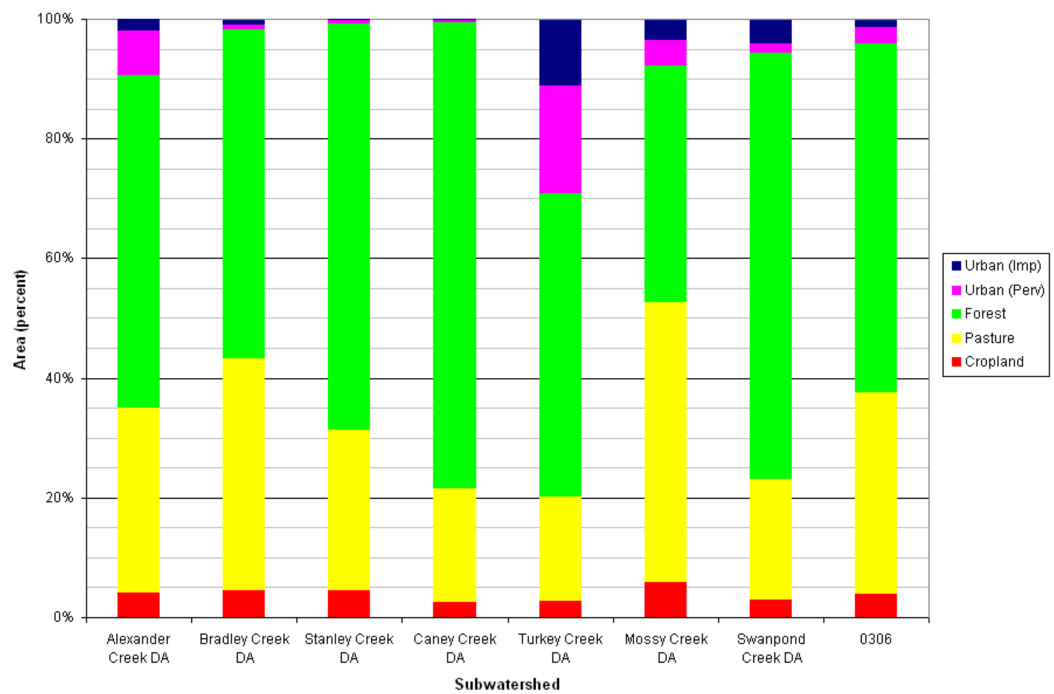

Figure 10. Land Use Percent of the Holston River E. coli-Impaired Subwatersheds – Drainage Areas Between 4,000 and 10,000 Acres

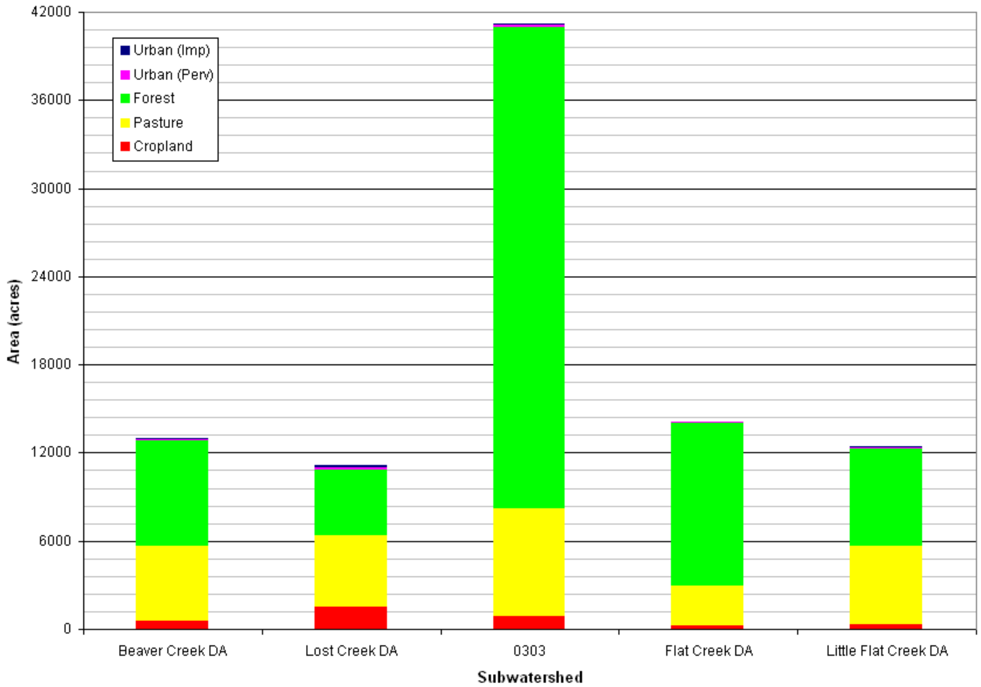

Figure 11. Land Use Area of Holston River E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres

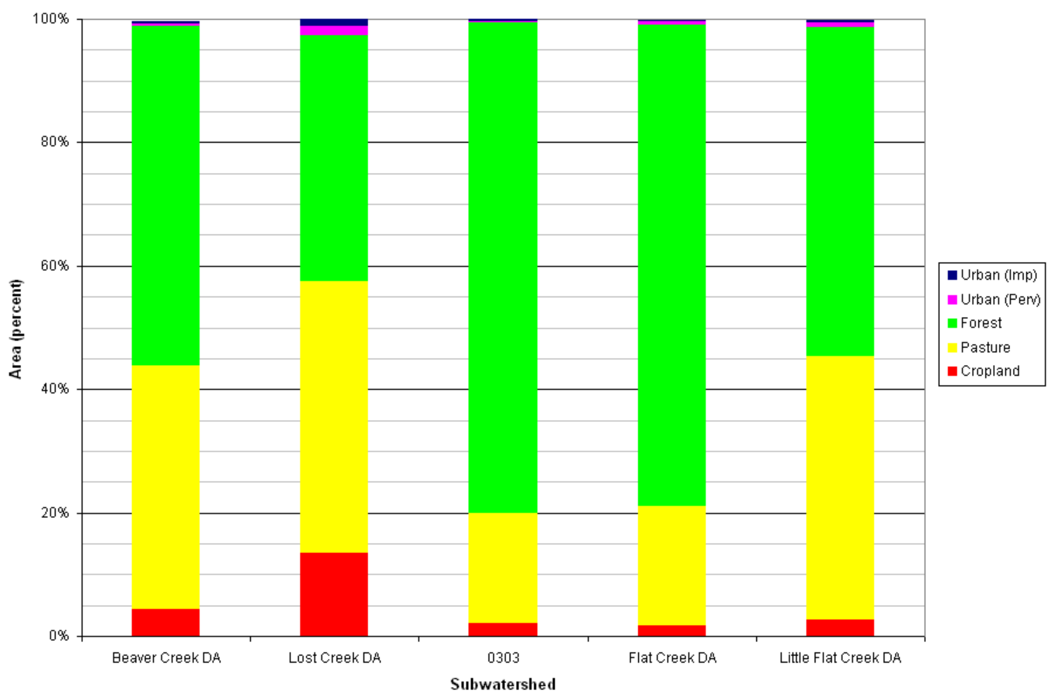

Figure 12. Land Use Percent of the Holston River E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) development for waterbodies identified as impaired due to E. coli on the Final 2008 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is a daily load expressed as a function of mean daily flow (daily loading function). For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease E. coli loads to TMDL target levels, within each respective flow zone, are also expressed. WLAs & LAs for precipitation-induced loading sources are also expressed as daily loading functions in CFU/day/acre. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for “other direct sources”) are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2008 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 7) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

Table 7 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (06010104____)	Impaired Waterbody	Area
0101	Alexander Creek	DA
	Hord Creek	DA
	Smith Creek	DA
0102	Bradley Creek	DA
	Forgey Creek	DA
	Hunt Creek	DA
	Renfroe Creek	DA
	Sinking Creek	DA
	Stoney Point Creek	DA
	Surgoinsville Creek	DA
0103	Stanley Creek	DA
0201	Crockett Creek	DA
0204	Caney Creek	DA
0207	Turkey Creek	DA
0210	Mossy Creek	DA
0302	Beaver Creek	DA
	Lost Creek	DA
0303	Richland Creek	HUC-12
0304	Swanpond Creek	DA
0305	Flat Creek	DA
	Little Flat Creek	DA
0306	Roseberry Creek	HUC-12

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Holston River Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS. In addition, load reductions (PLRGs) for each flow zone were calculated for prioritization of implementation measures according to the methods described in Appendix E.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from October 1, 1996 to September 30, 2006 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In all subwatersheds, water quality data have been collected during most flow ranges. For each Subwatershed, the critical flow zone has been identified based on the incremental levels of impairment relative to the target loads. Based on the location of the water quality exceedances on the load duration curves and the distribution of critical flow zones, no one delivery mode for E. coli appears to be dominant for waterbodies in the Holston River watershed (see Section 9.1.2 and 9.1.3 and Table 8).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. The water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of pathogen TMDLs in the Holston River Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters):	MOS = 49 CFU/100 ml
Instantaneous Maximum (all other waterbodies):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli daily loading functions were calculated for impaired segments in the Holston River watershed using LDCs to evaluate compliance with the single maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subwatersheds are shown in Table 8.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the available loading after application of the explicit MOS. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge (with few exceptions in Tennessee) and recognition that loading from these facilities are generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs, & LAs are summarized in Table 8.

Table 8 TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0101 (DA)	Alexander Creek	TN06010104011 – 0850	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.61 \times 10^{6} \times Q$	$3.61 \times 10^{6} \times Q$
0101 (DA)	Hord Creek	TN06010104011 – 0700	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.61 \times 10^{6} \times Q$	$5.61 \times 10^{6} \times Q$
0101 (DA)	Smith Creek	TN06010104011 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$1.09 \times 10^{7} \times Q$	$1.09 \times 10^{7} \times Q$
0102 (DA)	Bradley Creek	TN06010104011 – 0500	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.84 \times 10^{6} \times Q$	$2.84 \times 10^{6} \times Q$
0102 (DA)	Forgey Creek	TN06010104011 – 0200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	1.50×10^{9}	0	NA	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$
0102 (DA)	Hunt Creek	TN06010104011 – 1600	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$8.90 \times 10^{6} \times Q$	$8.90 \times 10^{6} \times Q$
0102 (DA)	Renfroe Creek	TN06010104011 – 0510	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.48 \times 10^{6} \times Q$	$5.48 \times 10^{6} \times Q$
0102 (DA)	Sinking Creek	TN06010104011 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.62 \times 10^{7} \times Q$	$1.62 \times 10^{7} \times Q$
0102 (DA)	Stoney Point Creek	TN06010104011 – 0400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.42 \times 10^{6} \times Q$	$5.42 \times 10^{6} \times Q$
0102 (DA)	Surgoinsville Creek	TN06010104011 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$7.33 \times 10^{6} \times Q$	$7.33 \times 10^{6} \times Q$
0103 (DA)	Stanley Creek	TN06010104015 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$4.82 \times 10^{6} \times Q$	$4.82 \times 10^{6} \times Q$
0201 (DA)	Crockett Creek	TN06010104004T – 1200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$7.01 \times 10^{6} \times Q$	$7.01 \times 10^{6} \times Q$
0204 (DA)	Caney Creek	TN06010104004T – 1150	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.27 \times 10^{6} \times Q$	$2.27 \times 10^{6} \times Q$
0207 (DA)	Turkey Creek	TN06010104004T – 2100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$3.97 \times 10^{9} \times Q_2$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$
0210 (DA)	Mossy Creek	TN06010104004T – 2400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.13 \times 10^{6} \times Q$	$3.13 \times 10^{6} \times Q$
0302 (DA)	Beaver Creek	TN06010104001 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.59 \times 10^{6} \times Q$	$1.59 \times 10^{6} \times Q$
0302 (DA)	Lost Creek	TN06010104001 – 0800	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.86 \times 10^{6} \times Q$	$1.86 \times 10^{6} \times Q$

Table 8 (cont'd). TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0303	Richland Creek	TN06010104018 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	7.40×10^{9}	0	NA	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$
0304 (DA)	Swanpond Creek	TN06010104001 – 1400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.21 \times 10^{6} \times Q$	$3.21 \times 10^{6} \times Q$
0305 (DA)	Flat Creek	TN06010104019 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.47 \times 10^{6} \times Q$	$1.47 \times 10^{6} \times Q$
0305 (DA)	Little Flat Creek	TN06010104019 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	$1.66 \times 10^{6} \times Q$	$1.66 \times 10^{6} \times Q$
0306	Roseberry Creek	TN06010104001 – 0500	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	$2.45 \times 10^{6} \times Q$	$2.45 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Industrial Point Source
CS = Collection Systems

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.

b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Holston River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

9.1 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve (LDC) methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting management strategies for appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point source problems. The load duration curve analysis can be utilized for implementation planning. See Cleland (2003) for further information on duration curves and TMDL development, and: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf .

9.1.1 Flow Zone Analysis for Implementation Planning

A major advantage of the duration curve framework in TMDL development is the ability to provide meaningful connections between allocations and implementation efforts (USEPA, 2006). Because the flow duration interval serves as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree), allocations and reduction goals can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allows the development of allocation tables (USEPA, 2006) (Appendix E), which can be used to guide potential implementation actions to most effectively address water quality concerns.

For the purposes of implementation strategy development, available E. coli data are grouped according to flow zones, with the number of flow zones determined by the HUC-12 subwatershed or drainage area size, the total contributing area (for non-headwater HUC-12s), and/or the baseflow characteristics of the waterbody. In general, for drainage areas greater than 40 square miles, the duration curves will be divided into five zones (Figure 13): high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). For smaller drainage areas, flows occurring in the low flow zone (baseflow conditions) are often extremely low and difficult to measure accurately. In many small drainage areas, extreme dry conditions are characterized by zero flow for a significant percentage of time. For this reason, the low flow zone is best characterized as a broader range of conditions (or percent time) with subsequently fewer flow zones. Therefore, for most HUC-12 subwatershed drainage areas less than 40 square miles, the duration curves will be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Some small (<40 mi^2) waterbody drainage areas have sustained baseflow (no zero flows) throughout their period of record. For these waterbodies, the duration curves will be divided into five zones.

Given adequate data, results (allocations and percent load reduction goals) will be calculated for all flow zones; however, less emphasis is placed on the upper 10% flow range for pathogen (E. coli) TMDLs and implementation plans. The highest 10 percent flows, representing flood conditions, are considered non-recreational conditions: unsafe for wading and swimming. Humans are not expected to enter the water due to the inherent hazard from high depths and velocities during these flow conditions. As a rule of thumb, the *USGS Field Manual for the Collection of Water Quality Data* (Lane, 1997) advises its personnel not to attempt to wade a stream for which values of depth (ft) multiplied by velocity (ft/s) equal or exceed 10 ft^2/s to collect a water sample. Few observations are typically available to estimate loads under these adverse conditions due to the difficulty and danger of sample collection. Therefore, in general, the 0-10% flow range is beyond the scope of pathogen TMDLs and subsequent implementation strategies.

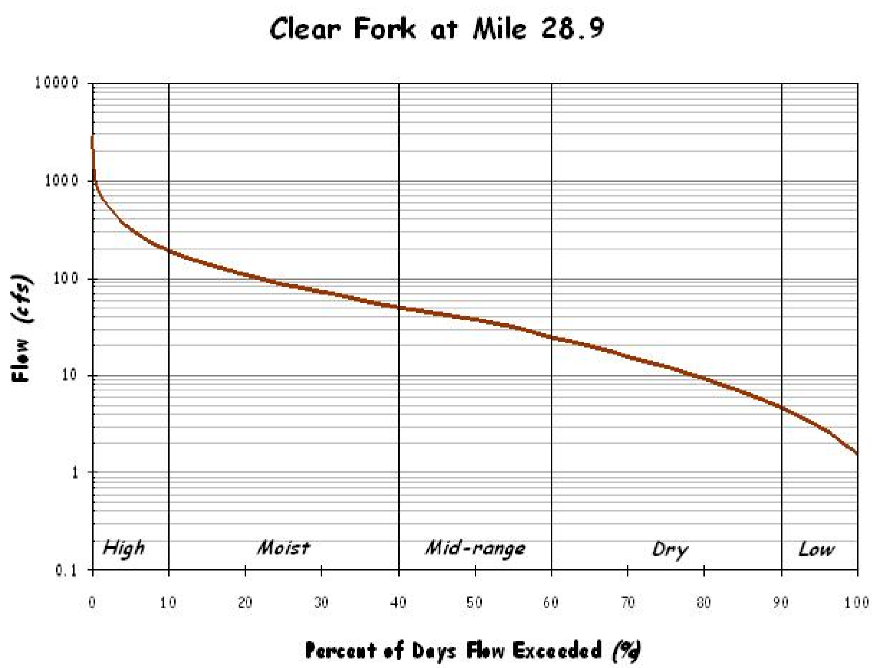

Figure 13. Five-Zone Flow Duration Curve for Clear Fork at RM 28.9

9.1.2 Existing Loads and Percent Load Reductions

Each impaired waterbody has a characteristic set of pollutant sources and existing loading conditions that vary according to flow conditions. In addition, maximum allowable loading (assimilative capacity) of a waterbody varies with flow. Therefore, existing loading, allowable loading, and percent load reduction expressed at a single location on the LDC (for a single flow condition) do not appropriately represent the TMDL in order to address all sources under all flow conditions (i.e., at all times) to satisfy implementation objectives. The LDC approach provides a methodology for determination of assimilative capacity and existing loading conditions of a waterbody for each flow zone. Subsequently, each flow zone, and the sources contributing to impairment under the corresponding flow conditions, can be evaluated independently. Lastly, the critical flow zone (with the highest percent load reduction goal) can be identified for prioritization of implementation actions.

Existing loading is calculated for each individual water quality sample as the product of the sample flow (cfs) times the single sample E. coli concentration (times a conversion factor). A percent load reduction is calculated for each water quality sample as that required to reduce the existing loading to the product of the sample flow (cfs) times the single sample maximum water quality standard (times a conversion factor). For samples with negative percent load reductions (non-exceedance: concentration below the single sample maximum water quality criterion), the percent reduction is assumed to be zero. The percent load reduction goal (PLRG) for a given flow zone is calculated a s the mean of all the percent load reductions for a given flow zone. See Appendix E.

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG, excluding the "high flow" zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG in this zone is greater than all the other zones, the zone with the second highest PLRG will be considered the critical flow zone. The critical conditions are such that if water quality standards were met under those conditions, they would likely be met overall.

9.2 Point Sources

9.2.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. With few exceptions, in Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.2.2 NPDES Regulated Municipal and Industrial Stormwater

9.2.2.1 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For present and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at: http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6 .

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see: http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%General%20Permit%202003.pdf .

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.
- Analytical monitoring of pollutants of concern (e.g., monthly) in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time. In addition, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of the monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.2.2.2 NPDES Regulated Industrial Stormwater

For present and future regulated stormwater discharges from industrial facilities, WLAs are and will be implemented through their NPDES permits. WLAs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day per acre.

9.2.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to most CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Provisions of the general permit include development and implementation of Nutrient Management Plan (NMPs), requirements regarding land application BMPs, and requirements for CAFO liquid waste management systems. For further information, see: http://state.tn.us/environment/wpc/permits/cafo.shtml.

9.3 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. An excellent example of stakeholder involvement is the Cumberland River Compact. The Cumberland River Compact is a non-profit group made up of businesses, individuals, community organizations, and agencies working in the Cumberland River watershed. Members of the Compact work with educators, landowners, contractors, marinas and other interested groups to coordinate informational education programs that encourage all of us to be better stewards of our water resources. The Compact works with local, state and federal agencies and officials to promote and strengthen cooperative working relationships and encourage the development of reliable, easy-to-understand data about water quality. Members of the Compact work with local communities to develop watershed forums where citizens come together to learn more about their watershed and participate in developing a shared vision for the future. The Compact also serves as a clearing-house of available public education programs to landowner assistance. Information regarding the accomplishments of the Cumberland River Compact is available at their website:

http://www.cumberlandrivercompact.org/.

9.3.1 Urban Nonpoint Sources

Management measures to reduce pathogen loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 9.2.2). Specific categories of urban nonpoint sources include stormwater, illicit discharges, septic systems, pet waste, and wildlife:

Stormwater: Most mitigation measures for stormwater are not designed specifically to reduce bacteria concentrations (ENSR, 2005). Instead, BMPs are typically designed to remove sediment and other pollutants. Bacteria in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in bacteria concentrations.

Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Septic systems: When properly installed, operated, and maintained, septic systems effectively reduce pathogen concentrations in sewage. To reduce the release of pathogens, practices can be employed to maximize the life of existing systems, identify failed systems, and replace or remove failed systems (USEPA, 2005a). Alternatively, the installation of public sewers may be appropriate.

Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA, 2002b).

Wildlife: Reducing the impact of wildlife on pathogen concentrations in waterbodies generally requires either reducing the concentration of wildlife in an area or reducing their proximity to the waterbody (ENSR, 2005). The primary means for doing this is to eliminate human inducements for congregation. In addition, in some instances population control measures may be appropriate.

Two additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://www.epa.gov/owow/nps/urbanmm/index.html) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap1.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban stormwater management (Publication Number EPA/600/R-04/184, September 2004).

9.3.2 Agricultural Nonpoint Sources

BMPs have been utilized in the Holston River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Holston River watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Holston River watershed are shown in Figure 14. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future modeling efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained, and their performance (in source reduction) evaluated over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

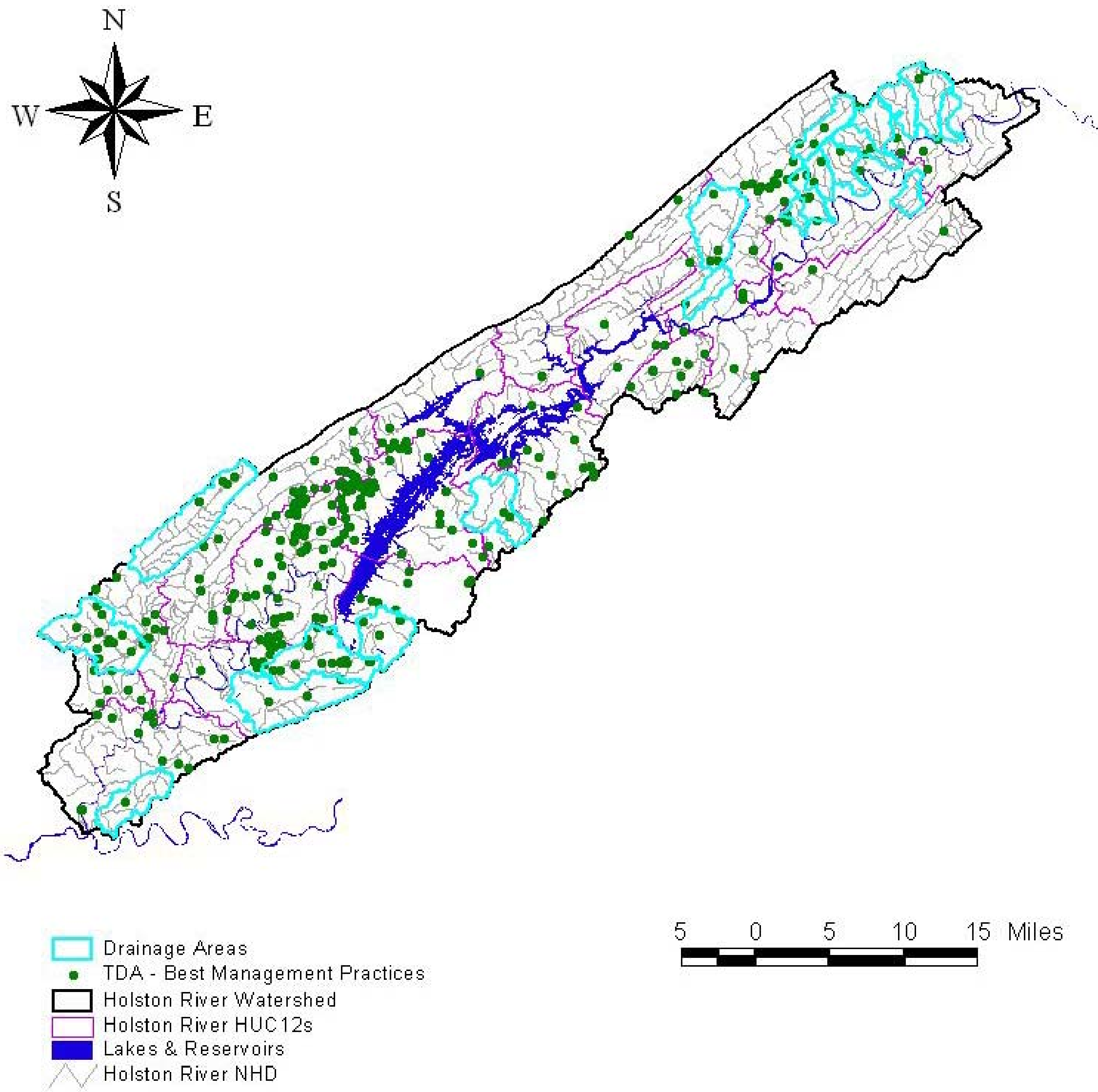

Figure 14. Tennessee Department of Agriculture Best Management Practices located in the Holston River Watershed.

For additional information on agricultural BMPs in Tennessee, see: http://state.tn.us/agriculture/nps/bmpa.ntml .

An additional agricultural nonpoint source resource provided by EPA is *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (http://www.epa.gov/owow/nps/agmm/index.html): a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and groundwater from agriculture (EPA 841-B-03-004, July 2003).

9.3.3 Other Nonpoint Sources

Additional nonpoint source references (not specifically addressing urban and/or agricultural sources) provided by EPA include:

National Management Measures to Control Nonpoint Source Pollution from Forestry (http://www.epa.gov/owow/nps/forestrymgmt/) helps forest owners protect lakes and streams from polluted runoff that can result from forestry activities. These scientifically sound techniques are the best practices known today. The report will also help states to implement their nonpoint source control programs (EPA 841-B-05-001, May 2005).

In addition, the EPA website, http://www.epa.gov/owow/nps/bestnpsdocs.html , contains a list of guidance documents endorsed by the Nonpoint Source Control Branch at EPA headquarters. The list includes documents addressing urban, agriculture, forestry, marinas, stream restoration, nonpoint source monitoring, and funding.

9.4 Additional Monitoring

Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of in-stream water quality targets for E. coli.

9.4.1 Water Quality Monitoring

Activities recommended for the Holston River watershed:

- Verify the assessment status of stream reaches identified on the Final 2008 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of TMDLs should be acquired. TMDLs will be revisited on 5-year watershed cycle as described above.

- Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by permittees and stakeholders. Where required TMDL loading reduction has been fully achieved, adequate data to support delisting should be collected.

- Provide additional data to clarify status of ambiguous sites (e.g., geometric mean data) for potential listing. Analyses of existing data at several monitoring sites on unlisted waterbodies in the Holston River watershed suggest levels of impairment. Therefore, additional data are required for listing determination.

- Continue ambient (long-term) monitoring at appropriate sites and key locations.

Comprehensive water quality monitoring activities include sampling during all seasons and a broad range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality*

System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC, 2004).

9.4.2 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as “genetic fingerprinting”), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) has developed and tested a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (Layton, 2006). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/JournalPapers/Layton06AEM.pdf .

BST technology was utilized in a study conducted in Stock Creek (Little River watershed) (Layton, 2004). Microbial source tracking using real-time PCR assays to quantify *Bacteroides* 16S rRNA genes was used to determine the percent of fecal contamination attributable to cattle. E. coli loads attributable to cattle were calculated for each of nine sampling sites in the Stock Creek subwatershed on twelve sampling dates. At the site on High Bluff Branch (tributary to Stock Creek), none of the sample dates had E. coli loads attributable to cattle above the threshold. This suggests that at this site removal of E. coli attributable to cattle would have little impact on the total E. coli loads. The E. coli load attributable to cattle made a large contribution to the total E. coli load at each of the eight remaining sampling sites. At two of the sites (STOCK005.3KN and GHOLL000.6KN), 50–75% of the E. coli attributable to cattle loads alone was above the 126 CFU/100mL threshhold. This suggests that removal of the E. coli attributable to cattle at these sites would reduce the total E. coli load to acceptable limits.

9.5 Source Area Implementation Strategy

Implementation strategies are organized according to the dominant landuse type and the sources associated with each (Table 9 and Appendix E). Each HUC-12 subwatershed is grouped and targeted for implementation based on this source area organization. Three primary categories are identified: predominantly urban, predominantly agricultural, and mixed urban/agricultural. See Appendix A for information regarding landuse distributation of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas with predominant source categories such as point sources (WWTFs), collection systems/septic systems (including SSOs and CSOs), and urban stormwater runoff associated with MS4s. Agricultural is defined as cropland and pasture, with predominant source categories associated with livestock and manure management activities. A fourth category (infrequent) is associated with forested (including non-agricultural undeveloped and unaltered [by humans]) landuse areas with the predominant source category being wildlife.

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Table 9. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

Appendix E provides source area implementation examples for urban and agricultural subwatersheds, development of percent load reduction goals, and determination of critical flow zones (for implementation prioritization) for E. coli impaired waterbodies. Load duration curve analyses (TMDLs, WLAs, LAs, and MOS) and percent load reduction goals for all flow zones for all E. coli impaired waterbodies in the Holston River watershed are summarized in Table E-44.

Table 9. Source area types for waterbody drainage area analyses.

Waterbody NameD	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Alexander Creek			✓	
Hord Creek		✓		
Smith Creek			✓	
Bradley Creek		✓		
Forgey Creek		✓		
Hunt Creek			✓	
Renfroe Creek		✓		
Sinking Creek		✓		
Stoney Point Creek		✓		
Surgoinsville Creek		✓		
Stanley Creek			✓	
Crockett Creek	✓			
Caney Creek			✓	
Turkey Creek	✓			
Mossy Creek	✓			
Beaver Creek		✓		
Lost Creek		✓		
Richland Creek		✓		
Swanpond Creek	✓			
Flat Creek			✓	
Little Flat Creek		✓		
Roseberry Creek			✓	

* All waterbodies potentially have significant source contributions from other source type/landuse areas.

9.5.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly urban, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 10 (USEPA, 2006). Table 10 presents example urban area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of urban management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

Table 10. Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	

Table 10 (cont'd). Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L
Note: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)					

9.5.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly agricultural, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 11 (USDA, 1988). Table 11 present example agricultural area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of agricultural management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominant source category being wildlife, in the Holston River watershed.

Table 11. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	**H**	**H**	**M**	**L**	
Pasture & Hayland Mgmt (510)	**H**	**H**	**M**	**L**	
Deferred Grazing (352)	**H**	**H**	**M**	**L**	
Planned Grazing System (556)	**H**	**H**	**M**	**L**	
Proper Grazing Use (528)	**H**	**H**	**M**	**L**	
Proper Woodland Grazing (530)	**H**	**H**	**M**	**L**	
Livestock Access Limitation					
Livestock Exclusion (472)			**M**	**H**	**H**
Fencing (382)			**M**	**H**	**H**
Stream Crossing			**M**	**H**	**H**
Alternate Water Supply					
Pipeline (516)			**M**	**H**	**H**
Pond (378)			**M**	**H**	**H**
Trough or Tank (614)			**M**	**H**	**H**
Well (642)			**M**	**H**	**H**
Spring Development (574)			**M**	**H**	**H**
Manure Management					
Managing Barnyards	**H**	**H**	**M**	**L**	
Manure Transfer (634)	**H**	**H**	**M**	**L**	
Land Application of Manure	**H**	**H**	**M**	**L**	
Composting Facility (317)	**H**	**H**	**M**	**L**	
Vegetative Stabilization					
Pasture & Hayland Planting (512)	**H**	**H**	**M**	**L**	
Range Seeding (550)	**H**	**H**	**M**	**L**	
Channel Vegetation (322)	**H**	**H**	**M**	**L**	
Brush (& Weed) Mgmt (314)	**H**	**H**	**M**	**L**	

Table 11 (cont'd). Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Vegetative Stabilization (cont'd)					
Conservation Cover (327)		**H**	**H**	**H**	
Riparian Buffers (391)		**H**	**H**	**H**	
Critical Area Planting (342)		**H**	**H**	**H**	
Wetland restoration (657)		**H**	**H**	**H**	
CAFO Management					
Waste Management System (312)	**H**	**H**	**M**		
Waste Storage Structure (313)	**H**	**H**	**M**		
Waste Storage Pond (425)	**H**	**H**	**M**		
Waste Treatment Lagoon (359)	**H**	**H**	**M**		
Mulching (484)	**H**	**H**	**M**		
Waste Utilization (633)	**H**	**H**	**M**		
Water & Sediment Control Basin (638)	**H**	**H**	**M**		
Filter Strip (393)	**H**	**H**	**M**		
Sediment Basin (350)	**H**	**H**	**M**		
Grassed Waterway (412)	**H**	**H**	**M**		
Diversion (362)	**H**	**H**	**M**		
Heavy Use Area Protection (561)					
Constructed Wetland (656)					
Dikes (356)	**H**	**H**	**M**		
Lined Waterway or Outlet (468)	**H**	**H**	**M**		
Roof Runoff Mgmt (558)	**H**	**H**	**M**		
Floodwater Diversion (400)	**H**	**H**	**M**		
Terrace (600)	**H**	**H**	**M**		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

Note: Numbers in parentheses are the U.S. Soil Conservation Service practice number.

9.6 Evaluation of TMDL Implementation Effectiveness

Evaluation of the effectiveness of TMDL implementation strategies should be conducted on multiple levels, as appropriate:

- HUC-12 or waterbody drainage area (i.e., TMDL analysis location)
- Subwatersheds or intermediate sampling locations
- Specific landuse areas (urban, pasture, etc.)
- Specific facilities (WWTF, CAFO, uniquely identified portion of MS4, etc.)
- Individual BMPs

In order to conduct an implementation effectiveness analysis on measures to reduce E. coli source loading, monitoring results should be evaluated in one of several ways. Sampling results can be compared to water quality standards (e.g., load duration curve analysis) for determination of impairment status, results can be compared on a before and after basis (temporal), or results can be evaluated both upstream and downstream of source reduction measures or source input (spatial). Considerations include period of record, data collection frequency, representativeness of data, and sampling locations.

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watershed in second or successive TMDL cycles, data collected from multiple cycles can be compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. For example, Figure 15 shows fecal coliform concentration data statistics for Oostanaula Creek at mile 28.4 (Hiwassee River watershed) for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL). The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Figure 16 shows a load duration curve analysis (of recent versus historical data) of fecal coliform loading statistics for Oostanaula Creek. Lastly, Figure 17 shows best fit curve analyses of flow (percent time exceeded) versus fecal coliform loading relationships (regressions) plotted against the LDC of the single sample maximum water quality standard. Note that Figures 15-17 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

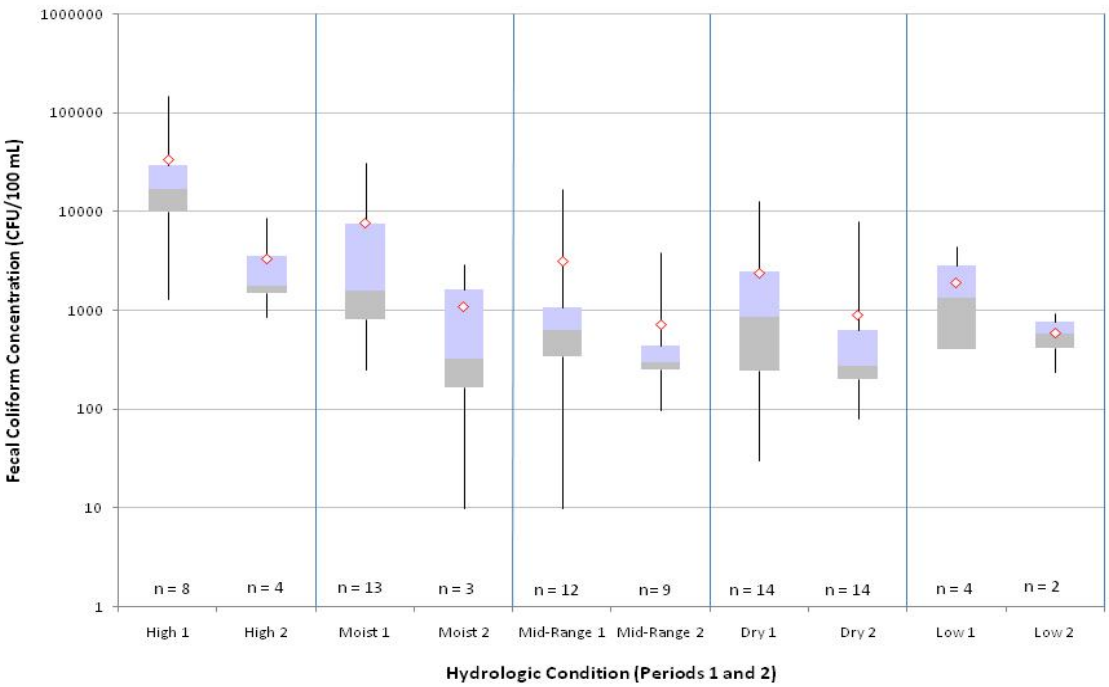

Figure 15. Oostanaula Creek TMDL implementation effectiveness (box and whisker plot).

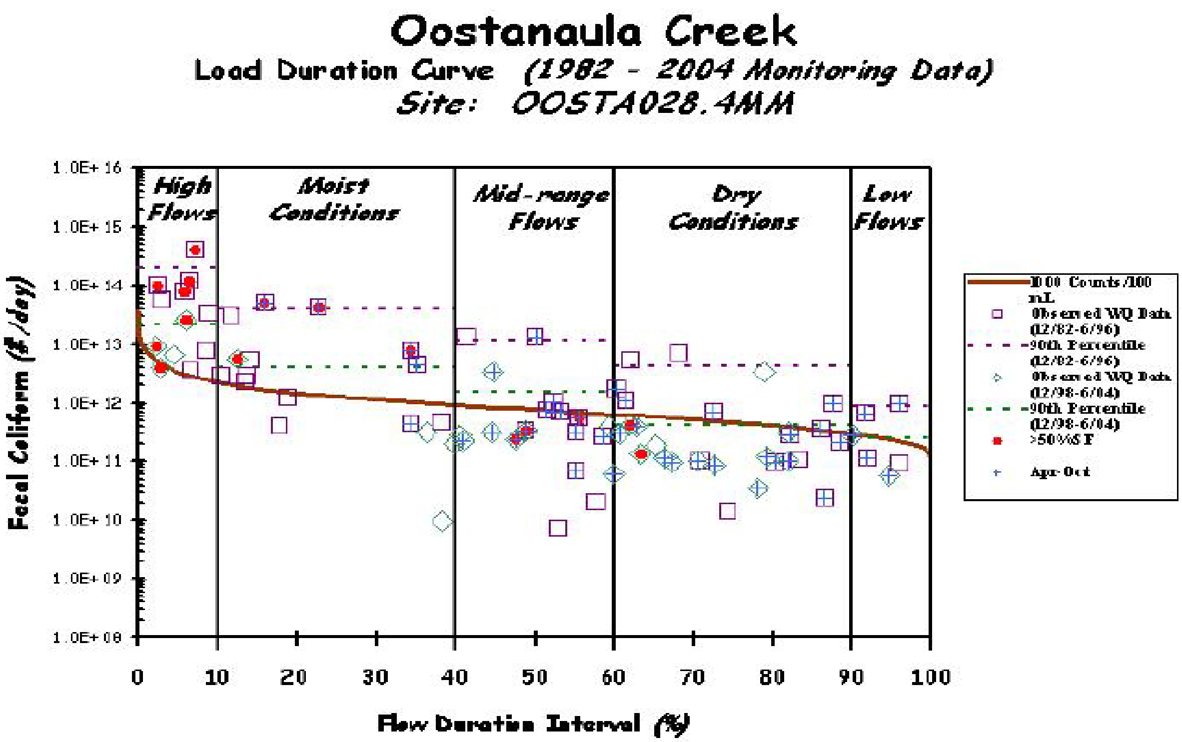

Figure 16. Oostanaula Creek TMDL implementation effectiveness (LDC analysis).

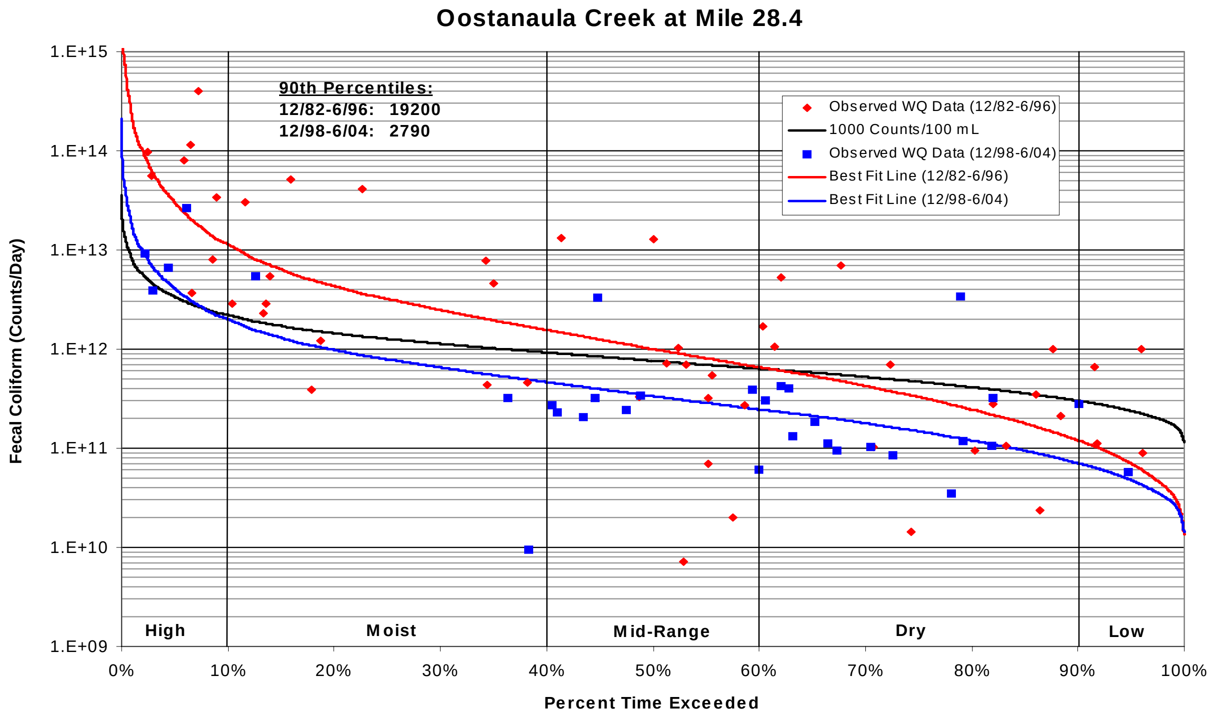

Figure 17. Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Holston River Watershed were placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters were sent to WWTFs located in E. coli-impaired subwatersheds or drainage areas in the Holston River Watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following facilities:

   Rutledge STP (TN0021105)
   Surgoinsville Middle & Elementary Schools (TN0055468)
   Joppa Elementary School (TN0074497)
   Rogersville STP (TN0020672)
   Jefferson City STP (TN0021199)
   Church Hill STP (TN0021253)
   KUB – Loves Creek STP (TN0021822)
   Morristown STP (TN0023507)
   KUB – East Bridge STP (TN0061743)
   Mount Carmel STP (TN0062057)
   Luttrell STP (TN0064149)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in E. coli-impaired subwatersheds. A draft copy was sent to the following entities:

   Hamblen County (TNS077763)
   Hawkins County (TNS075574)
   Knox County (TNS075582)
   Sevier County (TNS075655)
   Sullivan County (TNS075671)
   City of Knoxville (TNS068055)
   City of Church Hill (TNS075701)
   City of Kingsport (TNS075388)
   City of Morristown (TNS076031)
   City of Mount Carmel (TNS075744)
   Tennessee Dept. of Transportation (TNS077585)

5) A draft copy of the proposed TMDL was sent to those industrial facilities with individual stormwater permits that are wholly or partially located in E. coli-impaired subwatersheds. A draft copy was sent to the following entity:

Koch Foods LLC (TN0067989)

6) A letter was sent to water quality partners in the Holston River Watershed advising them of the proposed pathogen TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided upon request. A letter was sent to the following partners:

Caney Creek Watershed Partnership
Holston River Watershed Alliance
Smoky Mountain RC&D
Natural Resources Conservation Service
Tennessee Valley Authority
Tennessee Department of Agriculture
Tennessee Wildlife Resources Agency
The Nature Conservancy

No comments were received during the public notice period.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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REFERENCES

Center for Watershed Protection, 1999. *Watershed Protection Techniques*. Vol. 3. No. 1. Center for Watershed Protection. Ellicott City, MD. April 1999.

Cleland, Bruce, 2003. *TMDL Development from the "Bottom Up" – Part III: Duration Curves and Wet-Weather Assessments*. America's Clean Water Foundation. Washington, DC. September 2003. This document can be found at TMDLs.net, a joint effort of America's Clean Water Foundation, the Association of State and Interstate Water Pollution Control Administrators, and EPA: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf.

ENSR. 2005. *Mitigation Measures to Address Pathogen Pollution in Surface Waters: A TMDL Implementation Guidance Manual for Massachusetts*. Prepared by ENSR International for U.S. Environmental Protection Agency, Region 1. July 2005.

Hyer, Kenneth E., and Douglas L. Moyer, 2004. *Enhancing Fecal Coliform Total Maximum Daily Load Models Through Bacterial Source Tracking*. Journal of the American Water Resources Association (JAWRA) 40(6):1511-1526. Paper No. 03180.

Lane, S. L., and R. G. Fay, 1997. *National Field Manual for the Collection of Water-Quality Data, Chapter A9. Safety in Field Activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. 9*. October 1997. This document is available on the USGS website: http://water.usgs.gov/owq/FieldManual/Chap9/content.html.

Layton, Alice, Gentry, Randy, and McKay, Larry, 2004. *Calculation of Stock Creek E. coli loads and partitioning of E. coli loads in to that attributable to bovine using Bruce Cleland's Flow Duration Curve Models*. Personal note.

Layton, Alice, McKay, Larry, Williams, Dan, Garrett, Victoria, Gentry, Randall, and Sayler, Gary, 2006. *Development of Bacteriodes 16S rRNA Gene TaqMan-Based Real-Time PCR Assays for Estimation of Total Human, and Bovine Fecal Pollution in Water*. Applied and Environmental Microbiology (AEM), June 2006, p. 4214-4224. This document is available on the UTK website: http://web.utk.edu/~hydro/JournalPapers/Layton06AEM.pdf .

Lumb, A.M., McCammon, R.B., and Kittle, J.L., Jr., 1994, Users Manual for an expert system, (HSPFEXP) for calibration of the Hydrologic Simulation Program –Fortran: U.S. Geological Survey Water-Resources Investigation Report 94-4168,102 p.

Shah, Vikas G., Hugh Dunstan, and Phillip M. Geary, 2004. *Application of Emerging Bacterial Source Tracking (BST) Methods to Detect and Distinguish Sources of Fecal Pollution in Waters.* School of Environmental and Life Sciences, The University of Newcastle, Callaghan, NSW 2308 Australia. This document is available on the University of Newcastle website: http://www.newcastle.edu.au/discipline/geology/staff_pg/pgeary/BacterialSourceTracking.pdf.

Stiles, T., and B. Cleland, 2003, Using Duration Curves in TMDL Development & Implementation Planning. ASIWPCA "States Helping States" Conference Call, July 1, 2003. This document is available on the Indiana Office of Water Quality website: http://www.state.in.us/idem/programs/water/tmdl/durationcurveshscall.pdf .

TDEC. 2003. *General Permit for Discharges from Small Municipal Separate Storm Sewer Systems.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control, February 2003. This document is available on the TDEC website: http://state.tn.us/environment/wpc/stormh2o/MS4II.shtml.

TDEC. 2004. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2007. *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, 2007 Version.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2008. *Final 2008 303(d) List*. State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control, June 2008.

USDA, 1988. *1-4 Effects of Conservation Practices on Water Quantity and Quality*. In *Water Quality Workshop, Integrating Water Quality and Quantity into Conservation Planning*. U.S. Department of Agriculture, Soil Conservation Service. Washington, D.C.

USDA, 2004. *2002 Census of Agricultue, Tennessee State and County Data, Volume 1, Geographic Area Series, Part 42 (AC-02-A-42)*. USDA website URL: http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm . June 2004.

USEPA. 1991. *Guidance for Water Quality –based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

USEPA. 1997. *Ecoregions of Tennessee*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. EPA/600/R-97/022.

USEPA, 2002a. *Animal Feeding Operations Frequently Asked Questions*. USEPA website URL: http://cfpub.epa.gov/npdes/faqs.cfm?program_id=7 . September 12, 2002.

USEPA, 2002b. *Wastewater Technology Fact Sheet, Bacterial Source Tracking*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 832-F-02-010, May 2002. This document is available on the EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

USEPA. 2003. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. EPA 841-B-03-004. U.S. Environmental Protection Agency. Washington, DC. This document is available on the EPA website: http://www.epa.gov/owow/nps/agmm/index.html.

USEPA. 2004. *The Use of Best Management Practices (BMPs) in Urban Watersheds*. U.S. Environmental Protection Agency, Office of Research and Development. Washington, D.C. EPA/600/R-04/184, September 2004.

USEPA. 2005a. *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 841-B-05-004, November 2005. This document is available on the EPA website: http://www.epa.gov/owow/nps/urbanmm/index.html.

USEPA. 2005b. *National Management Measures to Control Nonpoint Source Pollution from Forestry*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 841-B-05-001, May 2005. This document is available on the EPA website: http://www.epa.gov/owow/nps/forestrymgmt/.

USEPA, 2006. *An Approach for Using Load Duration Curves in Developing TMDLs.* U.S. Environmental Protection Agency, Office of Wetlands, Oceans, & Watersheds. Washington, D.C. Draft, December 2006.

APPENDIX A

Land Use Distribution in the Holston River Watershed

Table A-1. MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Alexander Creek DA		Hord Creek DA		Smith Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	9.1	0.2	4.4	0.1	7.3	0.4
Deciduous Forest	1,561.2	27.2	979.0	26.5	429.4	22.6
Emergent Herbaceous Wetlands	2.2	0.0	0.0	0.0	0.4	0.0
Evergreen Forest	511.1	8.9	215.9	5.8	201.7	10.6
High Intensity Commercial/ Industrial/Transp.	50.0	0.9	0.7	0.0	42.9	2.3
High Intensity Residential	16.9	0.3	0.2	0.0	4.9	0.3
Low Intensity Residential	471.5	8.2	4.7	0.1	196.2	10.3
Mixed Forest	885.8	15.5	560.4	15.2	197.5	10.4
Open Water	1.1	0.0	0.0	0.0	0.9	0.0
Other Grasses (Urban/recreation; e.g. parks)	201.9	3.5	0.4	0.0	181.5	9.5
Pasture/Hay	1,773.8	31.0	1,638.8	44.4	594.5	31.2
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	238.2	4.2	279.6	7.6	42.9	2.3
Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	8.0	0.1	8.0	0.2	2.7	0.1
Total	5,721.8	100.0	3,687.8	100.0	1,895.5	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Bradley Creek DA		Forgey Creek DA		Hunt Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	15.8	0.2	3.6	0.1	0.9	0.0
Deciduous Forest	2,115.9	30.7	594.7	19.6	1,065.5	45.8
Emergent Herbaceous Wetlands	1.3	0.0	0.4	0.0	0.2	0.0
Evergreen Forest	505.1	7.3	227.3	7.5	199.5	8.6
High Intensity Commercial/ Industrial/Transp.	61.4	0.9	20.9	0.7	0.7	0.0
High Intensity Residential	1.1	0.0	0.0	0.0	0.0	0.0
Low Intensity Residential	46.9	0.7	37.8	1.2	32.7	1.4
Mixed Forest	1,102.6	16.0	520.6	17.2	550.2	23.7
Open Water	9.8	0.1	0.0	0.0	1.3	0.1
Other Grasses (Urban/recreation; e.g. parks)	25.4	0.4	85.0	2.8	2.4	0.1
Pasture/Hay	2,675.9	38.9	1,324.8	43.8	450.1	19.3
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	306.2	4.5	208.8	6.9	20.2	0.9
Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	13.8	0.2	3.8	0.1	2.4	0.1
Total	6,865.3	100.0	3,024.1	100.0	2,325.4	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Renfroe Creek DA		Sinking Creek DA		Stoney Point Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	7.6	0.2	0.4	0.0	12.7	0.3
Deciduous Forest	1,098.6	29.1	270.2	21.2	1,149.1	30.1
Emergent Herbaceous Wetlands	0.4	0.0	0.2	0.0	0.4	0.0
Evergreen Forest	253.8	6.7	97.2	7.6	329.6	8.6
High Intensity Commercial/ Industrial/Transp.	12.0	0.3	15.8	1.2	67.8	1.8
High Intensity Residential	0.4	0.0	0.0	0.0	0.0	0.0
Low Intensity Residential	30.7	0.8	0.2	0.0	72.9	1.9
Mixed Forest	545.3	14.4	214.8	16.8	699.7	18.3
Open Water	1.3	0.0	0.0	0.0	1.8	0.0
Other Grasses (Urban/recreation; e.g. parks)	16.9	0.4	25.8	2.0	17.6	0.5
Pasture/Hay	1,608.6	42.6	597.6	46.8	1,318.6	34.5
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	192.8	5.1	54.5	4.3	143.9	3.8
Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	7.3	0.2	0.2	0.0	8.0	0.2
Total	3,768.3	100.0	1,276.5	100.0	3,809.4	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Surgoinsville Creek DA		Stanley Creek DA		Crockett Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	3.8	0.1	6.0	0.1	0.0	0.0
Deciduous Forest	640.3	22.7	1873.5	43.6	772.8	26.2
Emergent Herbaceous Wetlands	0.2	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	215.9	7.6	355.6	8.3	324.0	11.0
High Intensity Commercial/ Industrial/Transp.	22.5	0.8	6.0	0.1	139.7	4.7
High Intensity Residential	0.2	0.0	0.0	0.0	108.1	3.7
Low Intensity Residential	33.8	1.2	26.9	0.6	346.5	11.7
Mixed Forest	518.0	18.3	669.2	15.6	594.9	20.2
Open Water	0.2	0.0	0.2	0.0	1.8	0.1
Other Grasses (Urban/recreation; e.g. parks)	42.0	1.5	8.7	0.2	185.3	6.3
Pasture/Hay	1,238.1	43.9	1148.7	26.7	387.9	13.1
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	105.4	3.7	195.7	4.6	90.3	3.1
Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	2.9	0.1	5.3	0.1	0.0	0.0
Total	2,819.5	100.0	4,289.8	100.0	2,951.2	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Caney Creek DA		Turkey Creek DA		Mossy Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	3,993.3	43.9	789.5	10.3	454.1	6.9
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	1,223.2	13.4	977.0	12.7	718.3	10.9
High Intensity Commercial/ Industrial/Transp.	24.0	0.3	523.1	6.8	157.0	2.4
High Intensity Residential	1.3	0.0	376.5	4.9	91.4	1.4
Low Intensity Residential	32.5	0.4	1,334.8	17.4	257.5	3.9
Mixed Forest	1,858.8	20.4	1,464.9	19.0	1,153.3	17.4
Open Water	0.9	0.0	10.7	0.1	7.3	0.1
Other Grasses (Urban/recreation; e.g. parks)	20.2	0.2	663.4	8.6	212.6	3.2
Pasture/Hay	1,717.8	18.9	1,343.3	17.5	3,088.4	46.7
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	75.6	1.1
Row Crops	234.0	2.6	209.7	2.7	393.0	5.9
Transitional	0.0	0.0	0.0	0.0	6.0	0.1
Woody Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total	9,106.0	100.0	7,692.9	100.0	6,614.7	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Beaver Creek DA		Lost Creek DA		0303 (incl. Richland Creek)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	3,167.8	24.4	1,331.7	12.0	17,813.2	43.2
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	1,373.3	10.6	1,114.6	10.0	5,611.7	13.6
High Intensity Commercial/ Industrial/Transp.	72.5	0.6	123.7	1.1	103.9	0.3
High Intensity Residential	0.2	0.0	11.3	0.1	16.9	0.0
Low Intensity Residential	36.7	0.3	167.0	1.5	125.9	0.3
Mixed Forest	2,229.1	17.2	1,786.5	16.1	9,263.2	22.5
Open Water	35.8	0.3	0.9	0.0	18.5	0.0
Other Grasses (Urban/recreation; e.g. parks)	43.1	0.3	177.7	1.6	70.5	0.2
Pasture/Hay	5,110.2	39.3	4,910.3	44.1	7,351.0	17.8
Quarries/Strip Mines/Gravel Pits	345.6	2.7	6.4	0.1	0.0	0.0
Row Crops	576.0	4.4	1,499.2	13.5	869.6	2.1
Transitional	1.8	0.0	0.2	0.0	4.4	0.0
Woody Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total	12,992.1	100.0	11,129.5	100.0	41,248.7	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area					
	Swanpond Creek DA		Flat Creek DA		Little Flat Creek DA	
	[acres]	[%]	[acres]	[%]		
Bare Rock/Sand/Clay	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	1,283.0	19.9	5,731.8	40.6	1,992.2	16.0
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	1,377.5	21.3	2,010.0	14.2	1,872.1	15.0
High Intensity Commercial/ Industrial/Transp.	290.7	4.5	26.0	0.2	62.3	0.5
High Intensity Residential	4.4	0.1	2.0	0.0	0.4	0.0
Low Intensity Residential	66.1	1.0	75.2	0.5	100.3	0.8
Mixed Forest	1,831.2	28.4	3,020.1	21.4	2,590.9	20.8
Open Water	8.0	0.1	26.5	0.2	12.9	0.1
Other Grasses (Urban/recreation; e.g. parks)	85.0	1.3	43.1	0.3	180.1	1.4
Pasture/Hay	1,306.6	20.2	2,723.4	19.3	5,319.5	42.7
Quarries/Strip Mines/Gravel Pits	0.0	0.0	215.1	1.5	0.0	0.0
Row Crops	187.7	2.9	253.1	1.8	328.7	2.6
Transitional	12.5	0.2	2.7	0.0	10.7	0.1
Woody Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total	6,452.6	100.0	14,129.0	100.0	12,470.1	100.0

Table A-1 (cont'd). MRLC Land Use Distribution of Holston River Subwatersheds

Land Use	HUC-12 Subwatershed (06010104__) or Drainage Area	
	0306 (incl. Roseberry Creek)	
	[acres]	[acres]
Deciduous Forest	0.0	0.0
Emergent Herbaceous Wetlands	1,382.6	1,382.6
Evergreen Forest	0.0	0.0
High Intensity Commercial/ Industrial/Transp.	1,472.3	1,472.3
High Intensity Residential	77.2	77.2
Low Intensity Residential	13.8	13.8
Mixed Forest	251.3	251.3
Open Water	1,727.1	1,727.1
Other Grasses (Urban/recreation; e.g. parks)	10.7	10.7
Pasture/Hay	336.5	336.5
Quarries/Strip Mines/Gravel Pits	2,851.3	2,851.3
Row Crops	0.0	0.0
Transitional	332.7	332.7
Woody Wetlands	0.0	0.0
Total	0.0	0.0

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Holston River Watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded by TDEC at these stations are tabulated in Table B-1.

Table B-1. TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
ALEXA000.6HS	2/23/00	26
	5/24/00	1553
	8/24/00	>2419
	11/2/00	131
	7/28/04	461
	8/18/04	410
	9/9/04	740
	10/20/04	299
	11/18/04	133
	12/20/04	70
	1/19/05	137
	2/23/05	100
	3/16/05	740
	4/21/05	365
	5/17/05	172
	6/8/05	548
ALEXA001.4HS	2/23/00	64
	5/24/00	1732.9
	8/24/00	>2419
	11/2/00	308
	7/28/04	727
	8/18/04	1320
	9/9/04	613
	10/20/04	740
	11/18/04	1986
	12/20/04	613
	1/19/05	630
	2/23/05	411
	3/16/05	1300
	4/21/05	613
	5/17/05	740
	6/8/05	1100

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BEAVE000.4JE	6/29/04	980
	7/20/04	1732
	7/29/04	1553
	8/3/04	461
	8/11/04	687
	8/17/04	613
	8/26/04	980
	9/22/04	276
	10/4/04	548
	10/7/04	461
BRADL000.1HS	7/27/04	57940
	8/17/04	1733
	9/8/04	5380
	10/14/04	1320
	11/16/04	816
	12/16/04	310
	1/12/05	4790
	2/16/05	387
	3/23/05	1350
	4/18/05	488
	5/11/05	1300
	6/21/05	3680
BRADL001.4HS	2/23/00	326
	5/24/00	>2419
	8/24/00	>2419
	11/2/00	108
	7/27/04	9870
	8/17/04	770
	9/8/04	1350
	10/14/04	630
	11/16/04	326
	12/16/04	520
	1/12/05	6270
	2/16/05	630
	3/23/05	5290

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BRADL001.4HS (cont'd)	4/18/05	1970
	5/11/05	687
	6/21/05	488
BRADL002.8HS	7/27/04	10500
	8/17/04	740
	9/8/04	12230
	10/14/04	1414
	11/16/04	770
	12/16/04	2230
	1/12/05	9340
	2/16/05	1210
	3/23/05	1414
	4/18/05	2590
	5/11/05	1300
	6/21/05	1046
CANEY009.1HS	3/1/00	1553
	6/8/00	236
	9/21/00	1553
	12/20/00	579
	7/21/04	727
	8/11/04	435
	9/1/04	276
	10/5/04	249
	11/9/04	740
	12/13/04	488
	1/11/05	488
	2/3/05	1220
	3/3/05	410
	4/12/05	461
	5/4/05	830
	6/2/05	3680
CROCK001.8HS	2/24/00	50
	5/24/00	2419
	8/24/00	2419
	11/2/00	44

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CROCK001.8HS (cont'd)	7/21/04	108
	8/11/04	214
	9/1/04	299
	10/5/04	291
	11/9/04	310
	12/13/04	461
	1/11/05	172
	2/3/05	310
	3/3/05	100
	4/12/05	520
	5/4/05	148
	6/2/05	5290
FLAT015.3UN	6/22/04	228
	6/28/04	461
	7/1/04	435
	7/7/04	770
	7/14/04	1046
	7/20/04	435
	7/22/04	313
	8/3/04	727
	8/16/04	727
	9/2/04	365
	9/23/04	387
	9/29/04	135
FORGE000.8HS	2/24/00	328
	5/24/00	>2419.2
	8/24/00	>2419
	11/2/00	272
	7/28/04	727
	8/18/04	5880
	9/9/04	2419
	10/20/04	520
	11/18/04	248
	12/20/04	300

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
FORGE000.8HS (cont'd)	1/19/05	130
	2/23/05	310
	3/16/05	1200
	4/21/05	109
	5/17/05	387
	6/20/05	365
HORD000.2HS	2/23/00	50
	5/24/00	1300
	11/20/00	127
	7/28/04	816
	8/18/04	310
	9/9/04	201
	10/20/04	345
	11/18/04	133
	12/20/04	100
	1/19/05	400
	2/23/05	310
	3/15/05	96
	4/21/05	921
	5/17/05	310
	6/8/05	770
HUNT001.0HS	2/2/00	45
	4/5/00	1414
	7/13/00	980
	10/5/00	1046
	7/21/04	179
	8/11/04	140
	9/1/04	1986
	10/5/04	167
	11/8/04	970
	11/9/04	613
	12/13/04	1

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
HUNT001.0HS (cont'd)	1/11/05	866
	2/3/05	9600
	3/3/05	100
	4/12/05	200
	5/4/05	200
	6/2/05	1060
LFLAT000.3KN	6/22/04	687
	6/28/04	727
	7/1/04	548
	7/7/04	1733
	7/14/04	2419
	7/20/04	517
	7/22/04	435
	8/3/04	435
	8/16/04	326
	9/2/04	272
	9/23/04	816
	9/29/04	399
LOST000.7JE	6/29/04	>2419
	7/20/04	2419
	7/29/04	2419
	8/3/04	1986
	8/11/04	2419
	8/17/04	400
	8/26/04	2419
	9/22/04	2419
	10/4/04	2419
	10/7/04	1986
LOST004.2JE	6/29/04	866
	7/20/04	921
	7/29/04	1986
	8/3/04	921
	8/11/04	687
	8/17/04	548
	8/26/04	1203

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
LOST004.2JE (cont'd)	9/22/04	326
	10/4/04	816
	10/7/04	2419
LOST008.6JE	6/29/04	921
	7/20/04	308
	7/29/04	1120
	8/3/04	816
	8/11/04	326
	8/17/04	1203
	8/26/04	929
	9/22/04	727
	10/4/04	32
	10/7/04	65
MOSSY001.3JE	6/29/04	548
	7/20/04	192
	7/29/04	2419
	8/3/04	1733
	8/11/04	73
	8/17/04	1986
	8/26/04	206
	9/22/04	345
	10/4/04	157
	10/7/04	91
RENFR000.2HS	2/23/00	1120
	5/24/00	980
	8/24/00	>2419
	11/2/00	35
	7/27/04	38730
	8/17/04	345
	9/8/04	1850
	10/14/04	310
	11/16/04	214
	12/16/04	200

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
RENFR000.2HS (cont'd)	1/12/05	1340
	2/16/05	630
	3/23/05	816
	4/18/05	740
	5/11/05	520
	6/21/05	200
RENFR001.0HS	7/27/04	22820
	8/17/04	548
	9/8/04	1986
	10/14/04	387
	11/16/04	172
	12/16/04	200
	1/12/05	1600
	2/16/05	310
	3/23/05	2920
	4/18/05	200
	5/11/05	291
	6/21/05	200
RICHL000.8GR	6/29/04	345
	7/20/04	157
	7/29/04	285
	8/3/04	378
	8/11/04	1120
	8/17/04	613
	8/26/04	1203
	9/22/04	548
	10/4/04	435
	10/7/04	272
RICHL014.4GR	6/29/04	326
	7/20/04	190
	7/29/04	345
	8/3/04	687
	8/11/04	770
	8/14/04	299
	8/26/04	192

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
RICHL014.4GR (cont'd)	9/22/04	249
	10/1/04	238
	10/7/04	816
ROSEB000.6KN	5/26/04	727
	6/29/04	365
	7/20/04	276
	7/29/04	548
	8/3/04	291
	8/11/04	330
	8/17/04	1300
	9/22/04	548
	10/1/04	517
	10/7/04	285
SINKI001.1HS	2/24/00	>2419
	5/24/00	2419.2
	8/24/00	2419
	11/2/00	2419
	7/28/04	980
	8/18/04	1580
	9/9/04	866
	10/20/04	740
	11/18/04	133
	12/20/04	100
	1/19/05	47
	2/23/05	135
	3/16/05	100
	4/21/05	1553
	5/17/05	310
	6/20/05	2419
SMITH000.9HS	2/23/00	14
	5/24/00	1203.3
	8/24/00	>2419
	7/28/04	770
	8/18/04	200
	9/9/04	620

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SMITH000.9HS (cont'd)	10/20/04	300
	11/18/04	36
	12/20/04	100
	1/19/05	28
	2/23/05	18
	3/15/05	200
	4/21/05	119
	5/17/05	200
	6/8/05	980
SPOIN000.1HS	2/24/00	53
	5/24/00	>2419
	8/24/00	>2419
	11/2/00	461
	1/19/04	313
	7/28/04	1553
	8/18/04	200
	9/9/04	740
	10/20/04	630
	11/18/04	93
	12/20/04	200
	2/23/05	310
	3/15/05	200
	4/21/05	770
	5/17/05	517
	6/20/05	816
STANL000.1HS	3/1/00	308
	6/8/00	613
	9/21/00	2419
	12/20/00	222
	5/4/03	153
	7/21/04	411
	8/11/04	1120
	9/1/04	411
	9/1/04	435

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
STANL000.1HS (cont'd)	10/5/04	727
	11/9/04	236
	12/13/04	98
	1/11/05	249
	2/3/05	816
	3/3/05	100
SURGO000.1HS	2/24/00	84
	5/24/00	>2419
	8/24/00	1986
	11/2/00	167
	7/28/04	921
	8/18/04	730
	9/9/04	921
	10/20/04	1420
	11/18/04	548
	12/20/04	100
	1/19/05	100
	2/23/05	200
	3/15/05	100
	4/21/05	276
	5/17/05	310
	6/20/05	365
SWANP000.8KN	6/29/04	387
	7/20/04	179
	7/29/04	411
	8/3/04	272
	8/11/04	199
	8/17/04	548
	8/26/04	485
	9/22/04	345
	10/1/04	119
	10/4/04	119
	10/8/04	326

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Holston River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
TURKE001.7HA	6/29/04	>2419
	7/20/04	>2419
	7/29/04	2419
	8/3/04	>2419
	8/11/04	1986
	8/17/04	1986
	8/26/04	548
	9/22/04	2419
	10/1/04	1300
	10/7/04	980

APPENDIX C

Load Duration Curve Development and Determination of Daily Loading

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Holston River Watershed using Load Duration Curves (LDCs).). Daily loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function).

C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily discharges of flow over an extended period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from U.S. Geological Survey (USGS) continuous-record stations (http://waterdata.usgs.gov/tn/nwis/sw) located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Holston River Watershed were derived from LSPC hydrologic simulations based on parameters derived from calibrations at USGS Station No. 03491000 (see Appendix D for details of calibration). For example, a flow-duration curve for Alexander Creek at RM 1.4 was constructed using simulated daily mean flow for the period from 10/1/96 through 9/30/06 (RM 1.4 corresponds to the location of monitoring station ALEXA001.4HS). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

C.1.2 Development of Load Duration Curves and TMDLs

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

E. coli load duration curves for impaired waterbodies in the Holston River Watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. Load duration curves and required load reductions were developed using the following procedure (Alexander Creek is shown as an example):

1. A target load-duration curve (LDC) was generated for Alexander Creek by applying the E. coli target concentration of 941 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Alexander Creek}}$ = (941 CFU/100 mL) x (Q) x (UCF)

   where: Target Load = TMDL (CFU/day)
   Q = daily instream mean flow
   UCF = the required unit conversion factor

   TMDL = (2.30x10^{10}) x (Q) CFU/day

2. Daily loads were calculated for each of the water quality samples collected at monitoring station ALEXA001.4HS (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. ALEXA001.4HS was selected for LDC analysis because it has multiple exceedances of the target concentration.

   Note: *In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data was available for some sampling dates.*

   Example – 8/24/00 sampling event:
   Modelled Flow = 2.11 cfs
   Concentration = 2419 CFU/100 mL
   Daily Load = 1.25x10^{11} CFU/day

3. Using the flow duration curves developed in C.1.1, the “percent of days the flow was exceeded” (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for is shown in Figure C-2.

LDCs of other impaired waterbodies were derived in a similar manner and are shown in Appendix E.

C.2 Development of WLAs & LAs

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

Expanding the terms:

$$\text{TMDL} = [\sum \text{WLAs}]_{\text{WWTF}} + [\sum \text{WLAs}]_{\text{MS4}} + [\sum \text{WLAs}]_{\text{CAFO}} + [\sum \text{LAs}]_{\text{DS}} + [\sum \text{LAs}]_{\text{SW}} + \text{MOS}$$

For E. coli TMDLs in each impaired subwatershed or drainage area, WLA terms include:

- $[\sum \text{WLAs}]_{\text{WWTF}}$ is the allowable load associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds or drainage areas. Since NPDES permits for these facilities specify that treated wastewater must meet in-stream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTFs are calculated from the facility design flow and the Monthly Average permit limit.
- $[\sum \text{WLAs}]_{\text{CAFO}}$ is the allowable load for all CAFOs in an impaired subwatershed or drainage area. All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:
  - o All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
  - o All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.
- $[\sum \text{WLAs}]_{\text{MS4}}$ is the allowable E. coli load for discharges from MS4s. E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events.

LA terms include:

- $[\sum \text{LAs}]_{\text{DS}}$ is the allowable E. coli load from “other direct sources”. These sources include leaking septic systems, illicit discharges, and animals access to streams. The LA specified for all sources of this type is zero CFU/day (or to the maximum extent feasible).

- $[\sum LAs]_{SW}$ represents the allowable E. coli loading from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit) as a result of the buildup/wash-off processes associated with storm events (i.e., precipitation induced).

Since $[\sum WLAs]_{CAFO} = 0$ and $[\sum LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

$$\text{TMDL} - \text{MOS} = [\text{WLAs}]_{WWTF} + [\sum \text{WLAs}]_{MS4} + [\sum \text{LAs}]_{SW}$$

As stated in Section 8.4, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of the percent load reductions necessary to achieve and WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Exceptional Tennessee Waters):

Target – MOS = (487 CFU/100 ml) – 0.1(487 CFU/100 ml)

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (other):

Target – MOS = (941 CFU/100 ml) – 0.1(941 CFU/100 ml)

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean: Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Daily Load Calculation

Since WWTFs discharge must comply with instream water quality criteria (TMDL target) at the point of discharge, WLAs for WWTFs are expressed as a constant term. In addition, WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal on a per unit area basis and may be expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream E. coli concentrations to TMDL target values minus MOS:

$$\text{WLA[MS4]} = \text{LA} = \{\text{TMDL} - \text{MOS} - \text{WLA[WWTFs]}\} / \text{DA}$$

where: DA = waterbody drainage area (acres)

Using Alexander Creek as an example:

$$\text{TMDL}_{\text{Alexander Creek}} = (941 \text{ CFU/100 mL}) \times (Q) \times (UCF)$$

$$= 2.30 \times 10^{10} \times Q$$

$MOS_{\text{Alexander Creek}} = TMDL \times 0.10 = 2.30 \times 10^{9} \times Q$

$$\mathbf{MOS = (2.30 \times 10^{9}) \times (Q)\ CFU/day}$$

$$WLA[MS4]_{\text{Alexander Creek}} = LA_{\text{Alexander Creek}}$$

$$= \{TMDL - MOS - WLA[WWTFs]\} / DA$$

$$= \{(2.30 \times 10^{10} \times Q) - (2.30 \times 10^{9} \times Q) - (0)\} / (5.06 \times 10^{3})$$

$$\mathbf{WLA[MS4] = LA = [4.089 \times 10^{6} \times Q]}$$

TMDLs, WLAs, & LAs for other impaired subwatersheds and drainage areas were derived in a similar manner and are summarized in Table C-1.

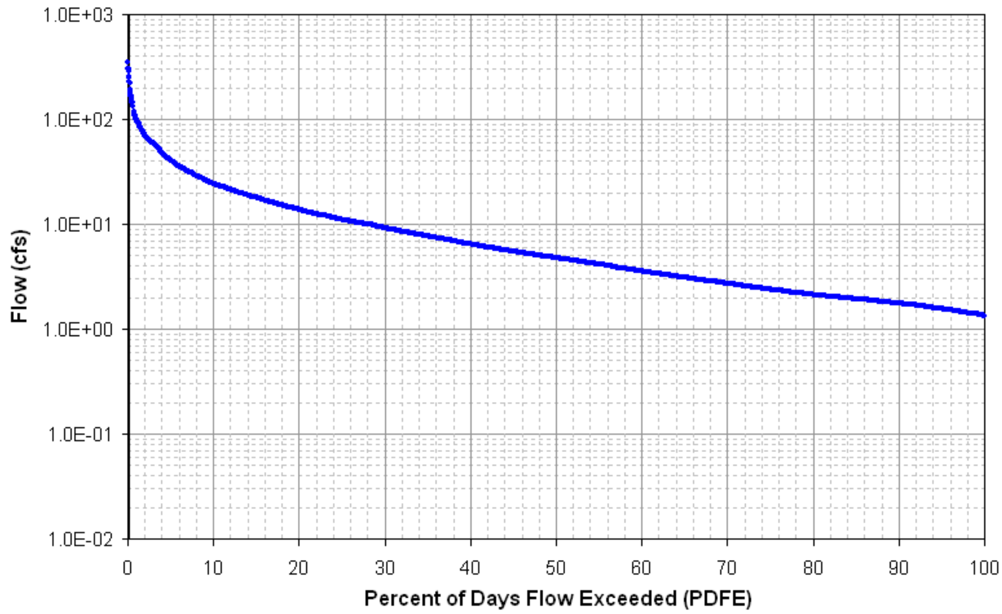

Figure C-1. Flow Duration Curve for Alexander Creek at Mile 1.4

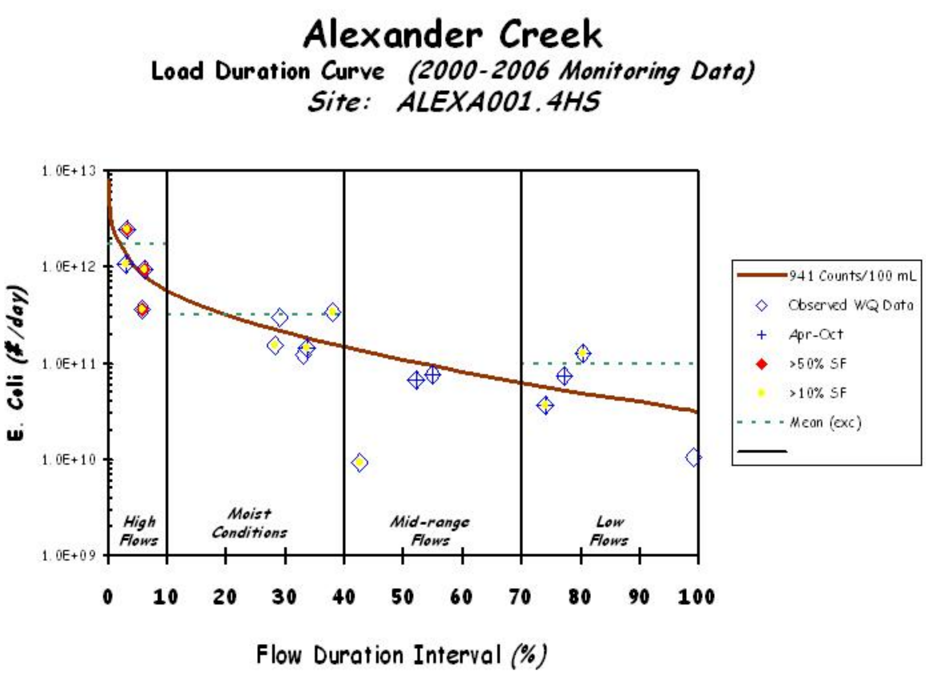

Figure C-2. E. Coli Load Duration Curve for Alexander Creek at Mile 1.4

Table C-1. TMDLs, WLAs, & LAs for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0101 (DA)	Alexander Creek	TN06010104011 – 0850	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.61 \times 10^{6} \times Q$	$3.61 \times 10^{6} \times Q$
0101 (DA)	Hord Creek	TN06010104011 – 0700	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.61 \times 10^{6} \times Q$	$5.61 \times 10^{6} \times Q$
0101 (DA)	Smith Creek	TN06010104011 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$1.09 \times 10^{7} \times Q$	$1.09 \times 10^{7} \times Q$
0102 (DA)	Bradley Creek	TN06010104011 – 0500	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.84 \times 10^{6} \times Q$	$2.84 \times 10^{6} \times Q$
0102 (DA)	Forgey Creek	TN06010104011 – 0200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	1.50×10^{9}	0	NA	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$	$(6.84 \times 10^{6} \times Q) - (4.95 \times 10^{5})$
0102 (DA)	Hunt Creek	TN06010104011 – 1600	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$8.90 \times 10^{6} \times Q$	$8.90 \times 10^{6} \times Q$
0102 (DA)	Renfroe Creek	TN06010104011 – 0510	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.48 \times 10^{6} \times Q$	$5.48 \times 10^{6} \times Q$
0102 (DA)	Sinking Creek	TN06010104011 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.62 \times 10^{7} \times Q$	$1.62 \times 10^{7} \times Q$
0102 (DA)	Stoney Point Creek	TN06010104011 – 0400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$5.42 \times 10^{6} \times Q$	$5.42 \times 10^{6} \times Q$
0102 (DA)	Surgoinsville Creek	TN06010104011 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$7.33 \times 10^{6} \times Q$	$7.33 \times 10^{6} \times Q$
0103 (DA)	Stanley Creek	TN06010104015 – 0300	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$4.82 \times 10^{6} \times Q$	$4.82 \times 10^{6} \times Q$
0201 (DA)	Crockett Creek	TN06010104004T – 1200	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$7.01 \times 10^{6} \times Q$	$7.01 \times 10^{6} \times Q$
0204 (DA)	Caney Creek	TN06010104004T – 1150	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$2.27 \times 10^{6} \times Q$	$2.27 \times 10^{6} \times Q$
0207 (DA)	Turkey Creek	TN06010104004T – 2100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$3.97 \times 10^{9} \times Q_2$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$	$(2.69 \times 10^{6} \times Q) - (3.97 \times 10^{9} \times Q_2)$
0210 (DA)	Mossy Creek	TN06010104004T – 2400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.13 \times 10^{6} \times Q$	$3.13 \times 10^{6} \times Q$
0302 (DA)	Beaver Creek	TN06010104001 – 0900	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.59 \times 10^{6} \times Q$	$1.59 \times 10^{6} \times Q$
0302 (DA)	Lost Creek	TN06010104001 – 0800	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.86 \times 10^{6} \times Q$	$1.86 \times 10^{6} \times Q$

Table C-1 (cont'd). TMDLs, WLAs, & LAs for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

HUC-12 Subwatershed (06010104__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs [a]	CS	Industrial NPDES	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
0303	Richland Creek	TN06010104018 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	7.40×10^{9}	0	NA	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$	$(5.02 \times 10^{5} \times Q) - (1.79 \times 10^{5})$
0304 (DA)	Swanpond Creek	TN06010104001 – 1400	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	NA	$3.21 \times 10^{6} \times Q$	$3.21 \times 10^{6} \times Q$
0305 (DA)	Flat Creek	TN06010104019 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	NA	$1.47 \times 10^{6} \times Q$	$1.47 \times 10^{6} \times Q$
0305 (DA)	Little Flat Creek	TN06010104019 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	$1.66 \times 10^{6} \times Q$	$1.66 \times 10^{6} \times Q$
0306	Roseberry Creek	TN06010104001 – 0500	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	$2.45 \times 10^{6} \times Q$	$2.45 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).
Q_2 = Mean Daily Flow (cfs) from Permitted Industrial Point Source
CS = Collection Systems

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.

b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.

APPENDIX D

Hydrodynamic Modeling Methodology

HYDRODYNAMIC MODELING METHODOLOGY

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Holston River Watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF)

D.2 Model Set Up

The Holston River Watershed was delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed "pour points" coincided with HUC-12 delineations, 303(d)-listed waterbodies, and water quality monitoring stations. Watershed delineation was based on the NHD stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support hydrology model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2006. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/96 – 9/30/06) used for TMDL analysis.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U. S. Geological Survey (USGS) stream gaging stations for the same period of time. A USGS continuous record station located in the Holston River Watershed with a sufficiently long and recent historical record was selected as the basis of the hydrology calibration. The USGS station was selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibration for Big Creek near Rogersville, USGS Station 03491000, drainage area 46.5 square miles, are shown in Table D-1 and Figures D-1 and D-2.

Table D-1. Hydrologic Calibration Summary: Big Creek near Rogersville (USGS 03491000)

			46.54168002	
	Simulation Name:	USGS03491000	**Simulation Period:**	
			Watershed Area (ac):	29796.21
	Period for Flow Analysis			
	Begin Date:	**10/01/96**	**Baseflow PERCENTILE:**	2.5
	End Date:	**09/30/06**	*Usually 1%-5%*	
	Total Simulated In-stream Flow:	**152.74**	Total Observed In-stream Flow:	**147.28**
	Total of highest 10% flows:	**85.01**	Total of Observed highest 10% flows:	**75.48**
	Total of lowest 50% flows:	**12.46**	Total of Observed Lowest 50% flows:	**12.71**
	Simulated Summer Flow Volume (months 7-9):	**17.06**	Observed Summer Flow Volume (7-9):	**10.40**
	Simulated Fall Flow Volume (months 10-12):	**28.32**	Observed Fall Flow Volume (10-12):	**25.19**
	Simulated Winter Flow Volume (months 1-3):	**61.91**	Observed Winter Flow Volume (1-3):	**65.58**
	Simulated Spring Flow Volume (months 4-6):	**45.44**	Observed Spring Flow Volume (4-6):	**46.11**
	Total Simulated Storm Volume:	**145.27**	Total Observed Storm Volume:	**139.74**
	Simulated Summer Storm Volume (7-9):	**15.18**	Observed Summer Storm Volume (7-9):	**8.53**
	Errors (Simulated-Observed)		*Recommended Criteria*	Last run
	Error in total volume:	**3.70**	10	
	Error in 50% lowest flows:	**-2.03**	10	
	Error in 10% highest flows:	**12.63**	15	
***	Seasonal volume error - Summer:	**63.97**	30	
	Seasonal volume error - Fall:	**12.42**	30	
	Seasonal volume error - Winter:	**-5.59**	30	
	Seasonal volume error - Spring:	**-1.45**	30	
	Error in storm volumes:	**3.96**	20	
***	Error in summer storm volumes:	**78.06**	50	

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

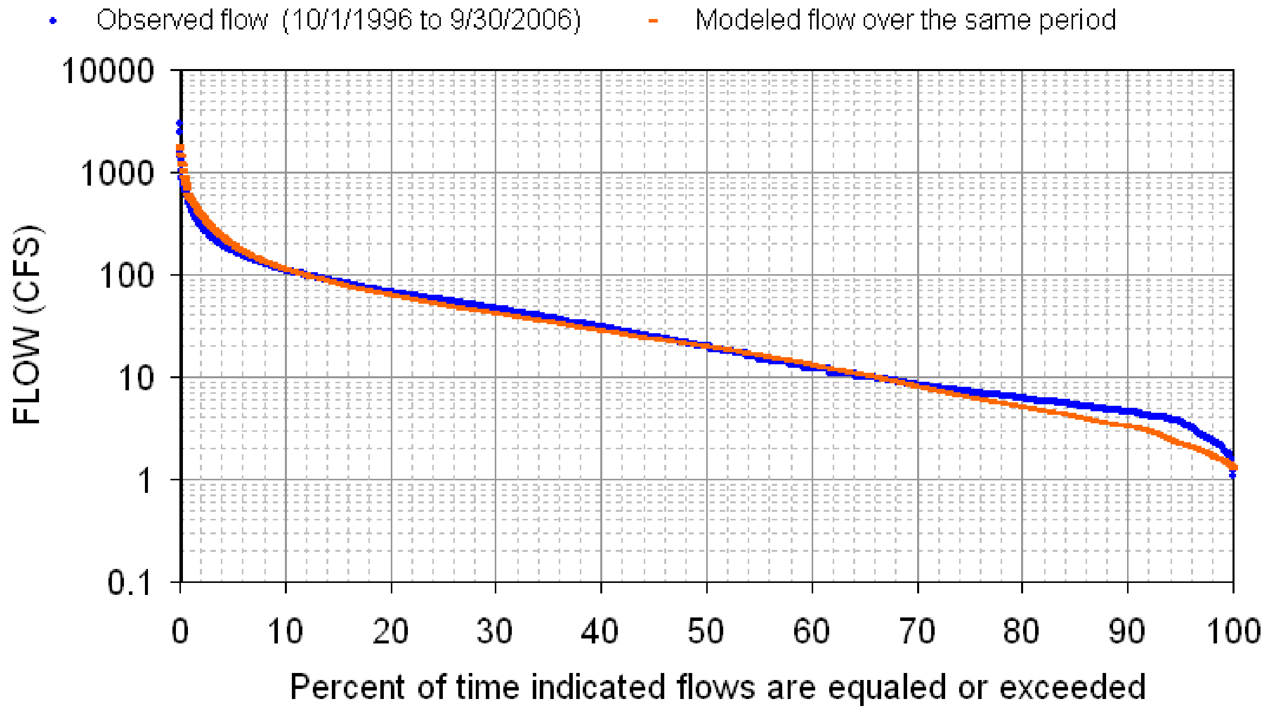

Figure D-1. Hydrologic Calibration: Big Creek, USGS 03491000 (WYs1997-2006)

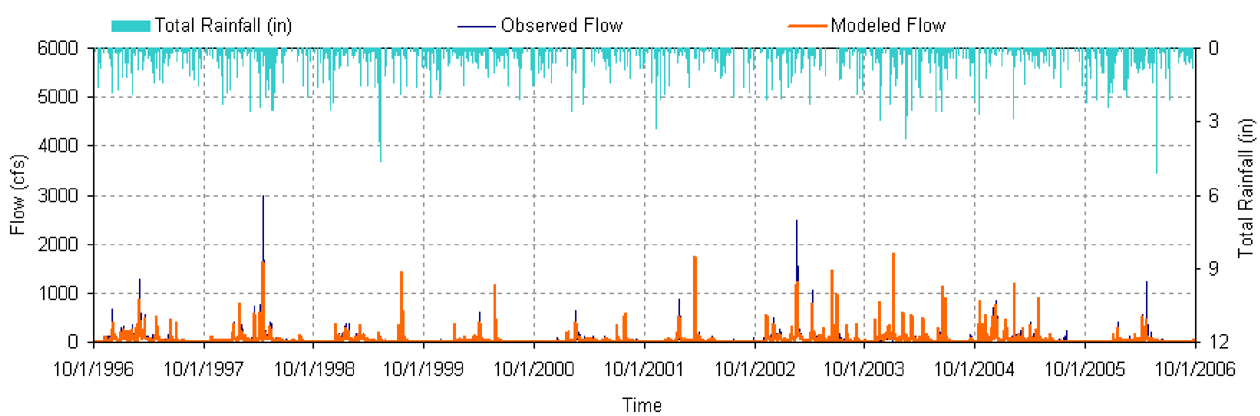

Figure D-2. 10-Year Hydrologic Comparison: Big Creek, USGS 03491000

APPENDIX E

Source Area Implementation Strategy

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Section 9.5, Table 9. The implementation for each area will be prioritized according to the guidance provided in Section 9.5.1 and 9.5.2, with examples provided in Section E.1 and E.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

E.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly urban source area types, the following example for Crockett Creek provides guidance for implementation analysis:

The Crockett Creek watershed, HUC-12 060101040201, lies near Rogersville. The drainage area for Crockett Creek at mile 1.8 is approximately 2,951 acres (4.6 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1).

Note: The Final 2008 303(d) List includes Discharges from MS4 Area as a Pollutant Source category for Crockett Creek; therefore, Crockett Creek is listed in the Urban source area type in Section 9.5, Table 9.

The flow duration curve for Crockett Creek at mile 1.8 was constructed using simulated daily mean flow for the period from 10/1/96 through 9/30/06 (mile 1.8 corresponds to the location of monitoring station CROCK001.8HS). This flow duration curve is shown in Figure E-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (Appendix C).

The E. coli LDC for Crockett Creek at Mile 1.8 (Figure E-2) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under multiple flow zones indicating the Crockett Creek watershed may be impacted by both point and non-point-type sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-5 thru E-31.

Critical conditions for the Crockett Creek watershed (HUC-12 060101040201) occur during mid-range flow conditions, typically indicative of non-point source contributions (see Table E-3, Section E.4). According to hydrograph separation analysis, the exceedances occurred during stormflow events. Therefore, it is reasonable to say that point type sources contribute to exceedances of the E. coli standard in Crockett Creek.

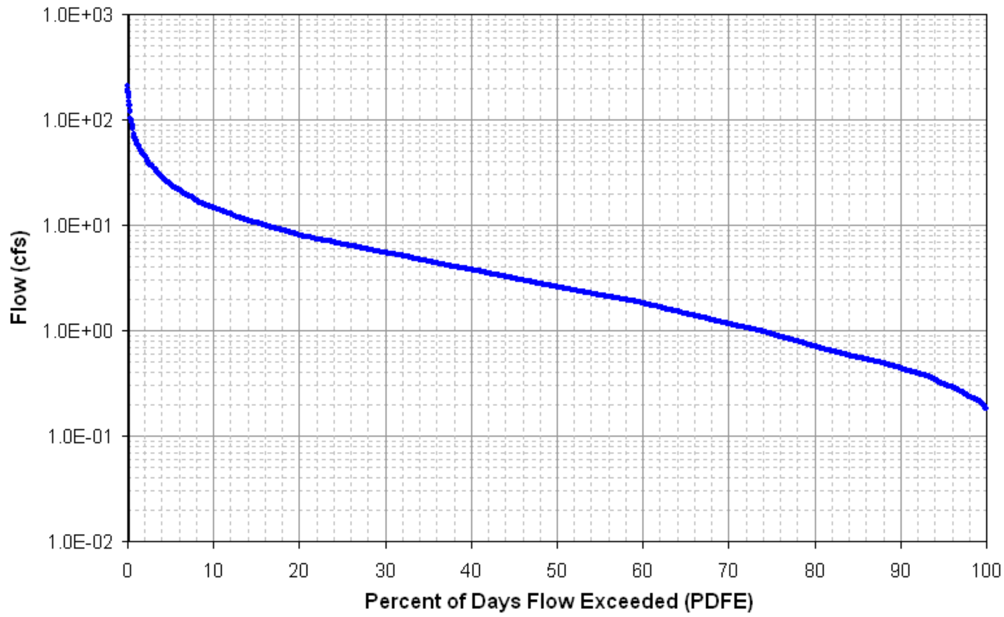

Figure E-1. Flow Duration Curve for Crockett Creek

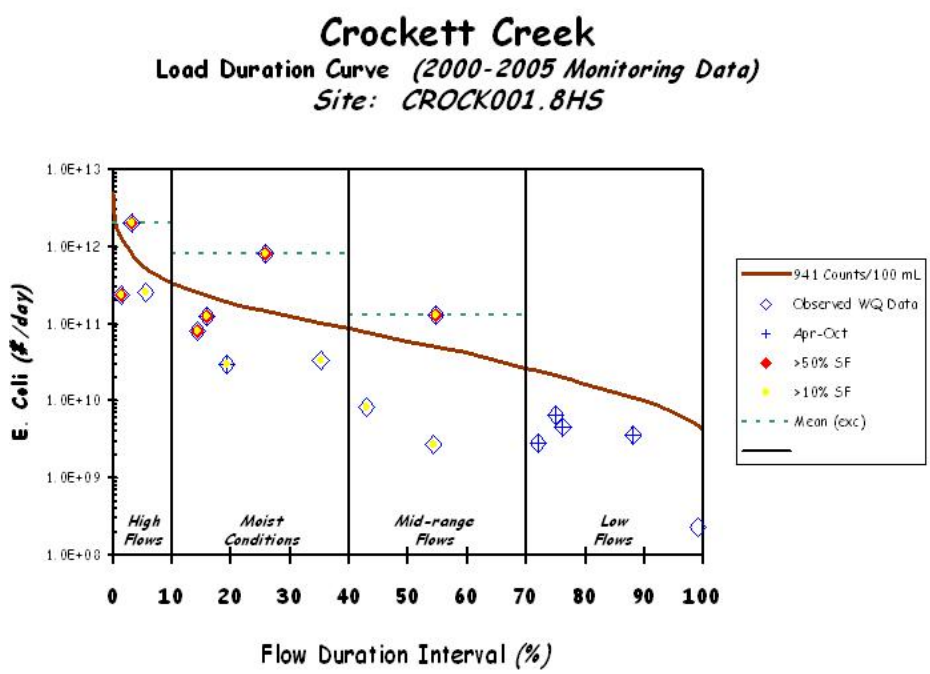

Figure E-2. E. Coli Load Duration Curve for Crockett Creek

Table E-1. Load Duration Curve Summary for Implementation Strategies (Example: Crockett Creek subwatershed, HUC-12 060101040201) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range*	Low
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Crockett Creek (060101040201)	Number of Samples	3	5	3	5
	% > 941 CFU/100 mL[1]	33.3	20.0	33.3	20.0
	Load Reduction[2]	20.4	16.4	20.4	NR
TMDL (CFU/day)		5.603E+11	1.511E+11	4.991E+10	1.288E+10
Margin of Safety (CFU/day)		5.603E+10	1.511E+10	4.991E+09	1.288E+09
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLAs (MS4s) (CFU/day/acre)[3]		NA	NA	NA	NA
LA (CFU/day/acre)[3]		1.709E+08	4.608E+07	1.522E+07	3.928E+06
Implementation Strategies[4]					
Municipal NPDES			L	M	H
Stormwater Management			H	H	
SSO Mitigation		H	M	L	
Collection System Repair			H	M	
Septic System Repair			L	M	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The Mid-Range Flow zone represents the critical conditions for E. coli loading in the Crockett Creek subwatershed.
1 Tennessee Maximum daily water quality criterion for E. coli.
2 Reductions (percent) based on mean of observed percent load reductions in range.
3 LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).
4 Watershed-specific Best Management Practices for Urban Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.

Results indicate the implementation strategy for the Crockett Creek watershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions) and non-point sources (dominant under high flow/runoff conditions). Table E-1 presents an allocation table of LDC analysis statistics for Crockett Creek E. coli and implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-1 are a subset of the categories of BMPs and implementation strategies available for application to the Holston River watershed for reduction of E. coli loading and mitigation of water quality impairment from urban sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly urban source area types can be derived from the information and results available in Tables 10 and E-44.

Table E-44 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Holston River watershed.

E.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly agricultural source area types, the following example for Sinking Creek provides guidance for implementation analysis:

The Sinking Creek subwatershed, HUC-12 060101040102, lies in a non-urbanized area of Hawkins county near Surgoinsville. The drainage area for Sinking Creek at Mile 1.1 is approximately 1,277 acres (2.0 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for Sinking Creek is approximately 51% agricultural, with most of the remainder being forested. Urban areas make up less than 1.3% of the total area. Therefore, the predominant landuse type and sources are agricultural.

The flow duration curve for Sinking Creek at Mile 1.1 was constructed using simulated daily mean flow for the period from 10/1/96 through 9/30/06. This flow duration curve is shown in Figure E-3 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (see Appendix C).

The E. coli LDC for Sinking Creek at Mile 1.1 (Figure E-4) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under most flow zones indicating the Sinking Creek watershed is impacted by point and non-point-type sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-5 thru E-31.

Critical conditions for the Sinking Creek HUC-12 occur during low flow conditions, typically indicative of point source contributions (see Table E-3, Section E.4). Exceedances of the E. coli water quality standard are fairly well distributed across the full range of flows and flow zones, though the magnitude of exceedances varies widely. According to hydrograph separation analysis, most of the exceedances occur during non-storm (baseflow) periods. These factors indicate that point sources are significant contributors to impairment in the Sinking Creek watershed. However, it is possible that both point and non-point type sources contribute to exceedances of the E. coli standard in Sinking Creek.

Results indicate the implementation strategy for the Sinking Creek watershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions). Table E-2 presents an allocation table of Load Duration Curve analysis statistics for Sinking Creek E. coli and targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-2 are a subset of the categories of BMPs and implementation strategies available for application to the Holston River watershed for reduction of E. coli loading and mitigation of water quality impairment from agricultural sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly agricultural source area types can be derived from the information and results available in Tables 11 and E-44.

Table E-44 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Holston River watershed.

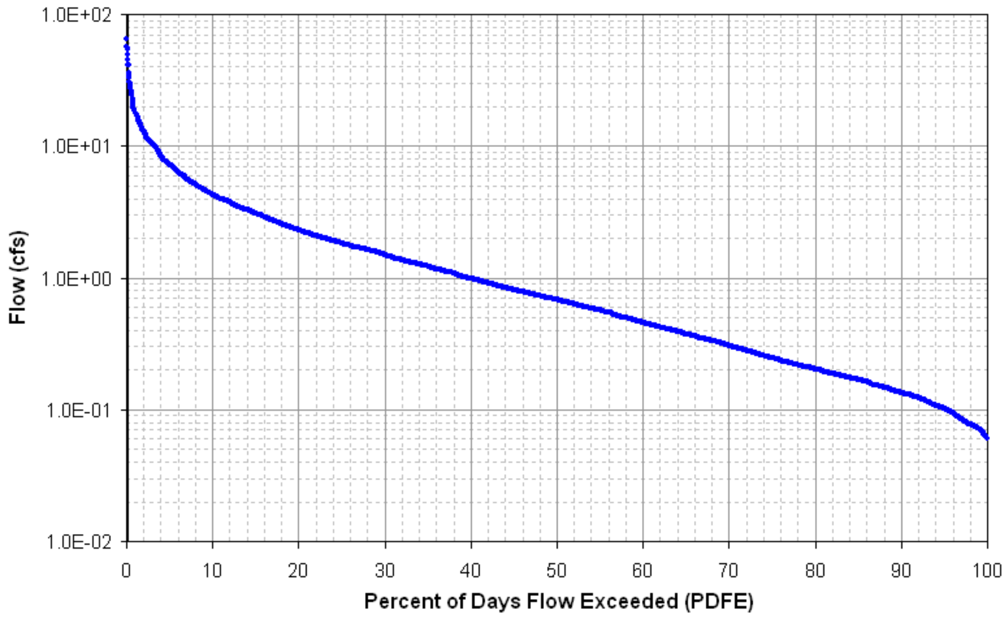

Figure E-3. Flow Duration Curve for Sinking Creek

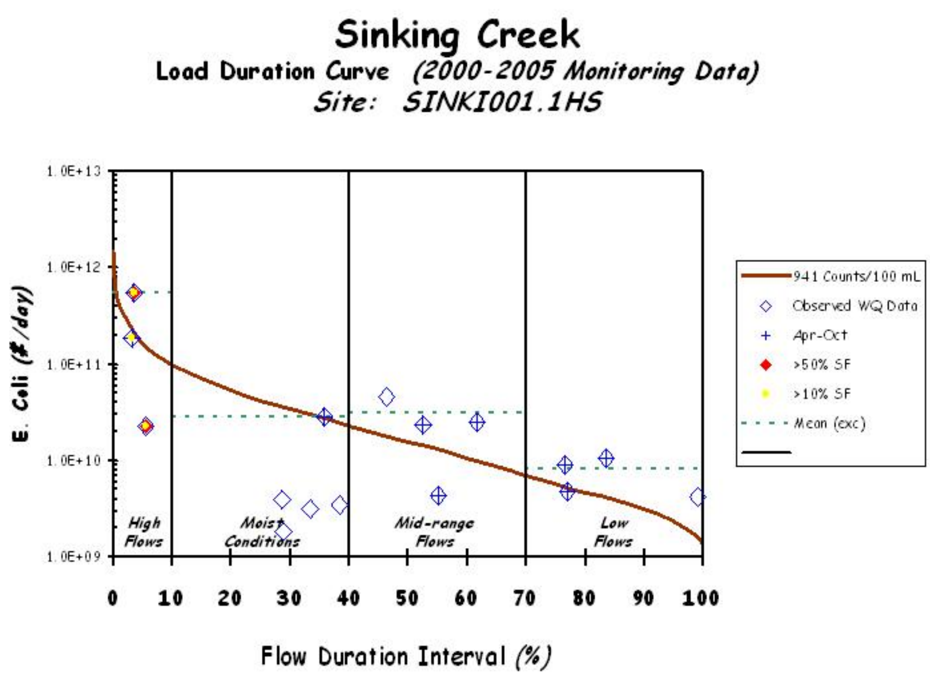

Figure E-4. E. Coli Load Duration Curve for Sinking Creek at Mile 1.1

Table E-2. Load Duration Curve Summary for Implementation Strategies (Example: Sinking Creek subwatershed, HUC-12 060101040102) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range*	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Sinking Creek (060101040102)	Number of Samples	3	5	4	4
	% > 941 CFU/100 mL[1]	33.3	20.0	75.0	75.0
	Load Reduction[2]	20.4	0.8	40.4	40.7
TMDL (CFU/day)		1.656E+11	4.209E+10	1.311E+10	3.910E+09
Margin of Safety (CFU/day)		1.656E+10	4.209E+09	1.311E+09	3.910E+08
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLA (MS4s) (CFU/day/acre)[3]		NA	NA	NA	NA
LAs (CFU/day/acre)[3]		1.626E+08	4.133E+07	1.287E+07	3.840E+06
Implementation Strategies[4]					
Pasture and Hayland Management		H	H	M	L
Livestock Exclusion				M	H
Fencing				M	H
Manure Management		H	H	M	L
Riparian Buffers		L	M	H	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The low flow zone represents the critical conditions for E. coli loading in the Sinking Creek subwatershed.
1 Tennessee Maximum daily water quality criterion for E. coli.
2 Reductions (percent) based on mean of observed percent load reductions in range.
3 LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).
4 Example Best Management Practices for Agricultural Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.

E.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominant source category being wildlife, in the Holston River watershed.

E.4 Calculation of Percent Load Reduction Goals and Determination of Critical Flow Zones

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream E. coli loads to TMDL target levels (percent load reduction goals) were calculated. The following example is from Sinking Creek at mile 1.8.

1. For each flow zone, the mean of the percent exceedances of individual loads relative to their respective target maximum loads (at their respective PDFEs) was calculated. Each negative percent exceedance was assumed to be equal to zero.

Date	Sample Conc. (CFU/100 mL)	Flow (cfs)	Existing Load (CFU/Day)	Target (TMDL) Load (CFU/Day)	Percent Reduction
8/18/04	1580	0.23	8.90E+09	5.30E+09	40.4
9/9/04	866	0.23	4.83E+09	5.25E+09	0 (-8.7)
8/24/00	2419	0.18	1.05E+10	4.10E+09	61.1
11/2/00	2419	0.07	4.15E+09	1.61E+09	61.1
Percent Load Reduction Goal (PLRG) for Low Flow Zone (Mean)					**40.7**

2. The PLRGs calculated for each of the flow zones, not including the high flow zone, were compared and the PLRG of the greatest magnitude indicates the critical flow zone for prioritizing implementation actions for Sinking Creek.

Example – *High Flow Zone Percent Load Reduction Goal = 20.4*
Moist Conditions Flow Zone Percent Load Reduction Goal = 0.8
Mid-Range Flow Zone Percent Load Reduction Goal = 40.4
Low Flow Zone Percent Load Reduction Goal = 40.7

Therefore, the critical flow zone for prioritization of Sinking Creek implementation activities is the Low Flow Zone and subsequently actions targeting point source controls.

PLRGs and critical flow zones of the other impaired waterbodies were derived in a similar manner and are shown in Table E-3.

Table E-3. Summary of Critical Conditions for Impaired Waterbodies in the Holston River Watershed.

Waterbody ID	Moist	Mid-range	Dry	Low
Alexander Creek				✓
Hord Creek		✓		
Smith Creek		✓		
Bradley Creek	✓			
Forgey Creek				✓
Hunt Creek				✓
Renfroe Creek	✓			
Sinking Creek				✓
Stoney Point Creek				✓
Surgoinsville Creek				✓
Stanley Creek				✓
Crockett Creek		✓		
Caney Creek		✓		
Turkey Creek	✓			
Mossy Creek	✓			
Beaver Creek		✓		
Lost Creek	✓			
Richland Creek		✓		
Swanpond Creek				
Flat Creek		✓		
Little Flat Creek		✓		
Roseberry Creek		✓		

* All Waterbody(ies) have 4 flow zones.

Geometric Mean Data

For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/100 mL. If the sample geometric mean exceeded the target geometric mean concentration, the reduction required to reduce the sample geometric mean value to the target geometric mean concentration was calculated.

Example: *Monitoring Location = Turkey Creek*
Sampling Period = 7/20/04 – 8/17/04
Geometric Mean Concentration = 2235.49 CFU/100 mL
Target Concentration = 126 CFU/100 mL
Reduction to Target = 94.4%

For impaired waterbodies where monitoring data are limited to geometric mean data only, results can be utilized for general indication of relative impairment and, when plotted on a load duration curve, may indicate areas for prioritization of implementation efforts. For impaired waterbodies where both types of data are available, geometric mean data may be utilized to supplement the results of the individual flow zone calculations.

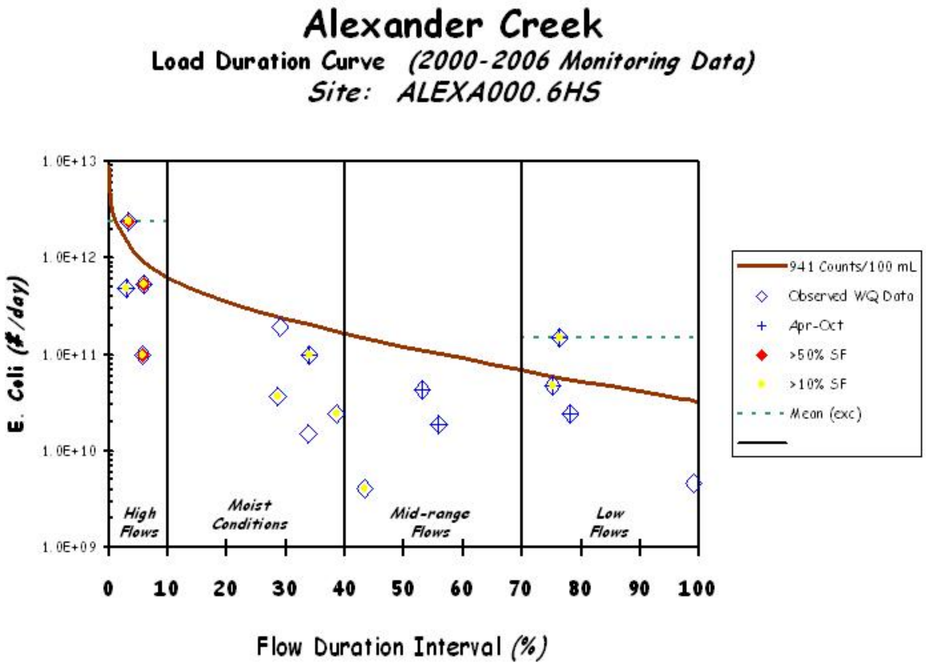

Figure E-5. E. Coli Load Duration Curve for Alexander Creek – RM0.4

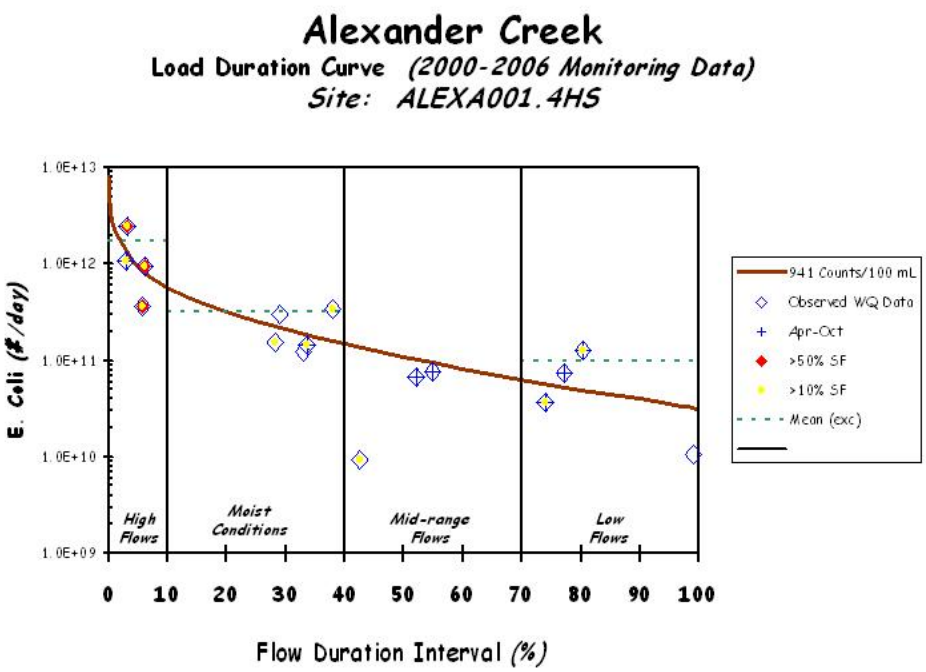

Figure E-6. E. Coli Load Duration Curve for Alexander Creek – RM1.4

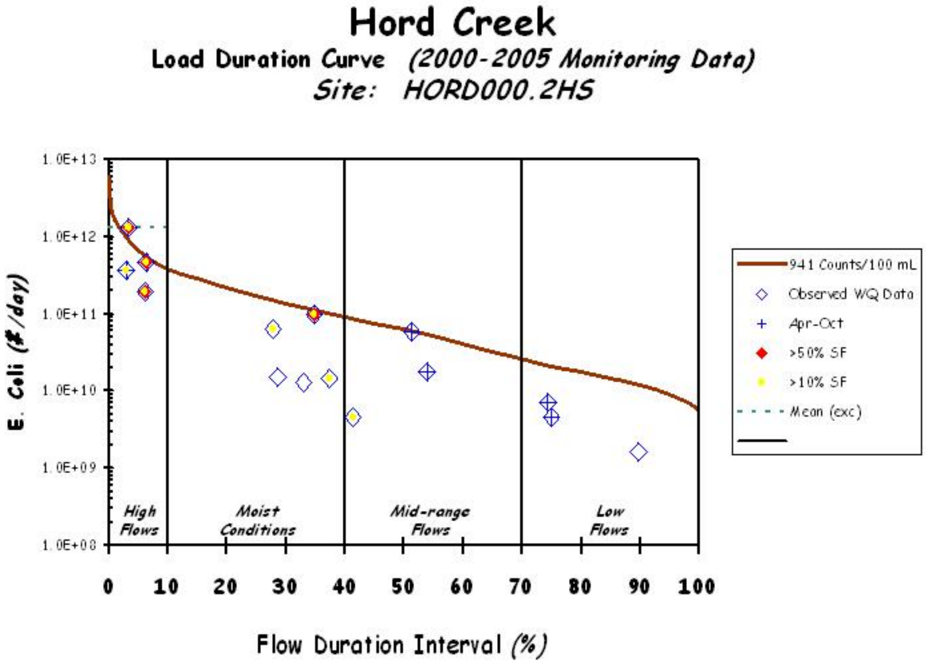

Figure E-7. E. Coli Load Duration Curve for Hord Creek

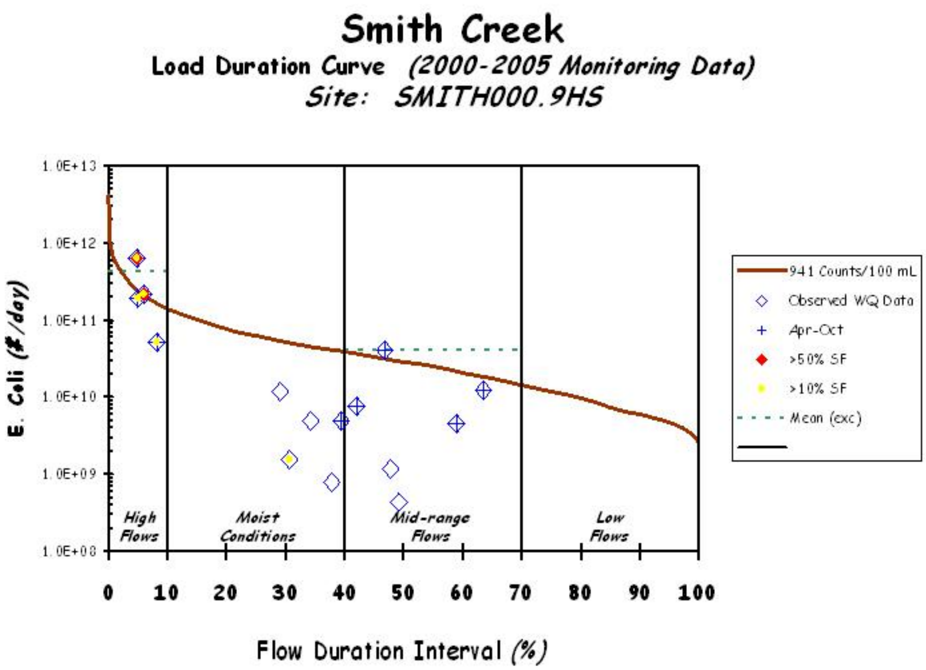

Figure E-8. E. Coli Load Duration Curve for Smith Creek

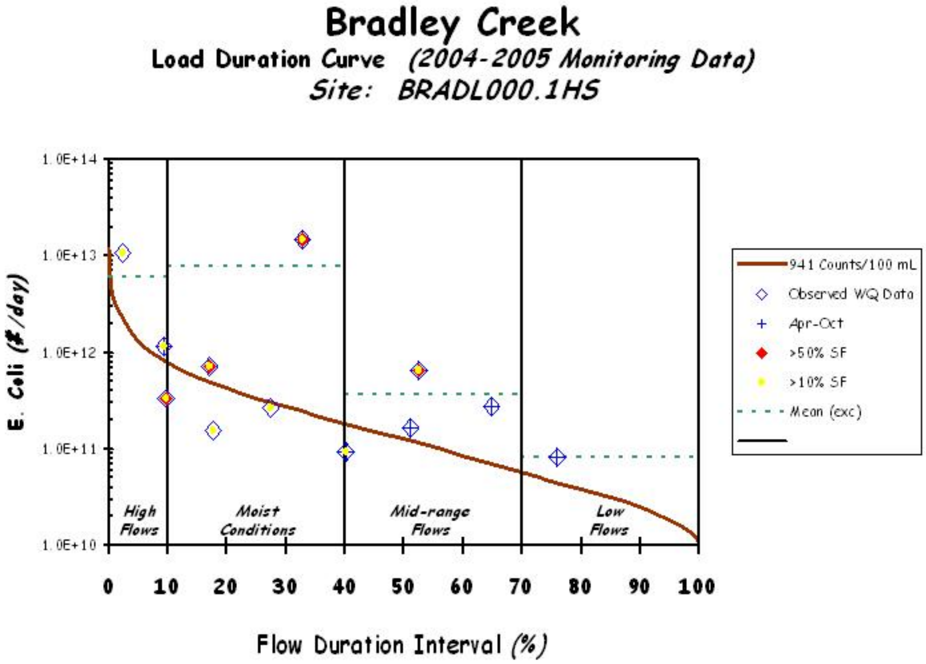

Figure E-9. E. Coli Load Duration Curve for Bradley Creek – RM0.1

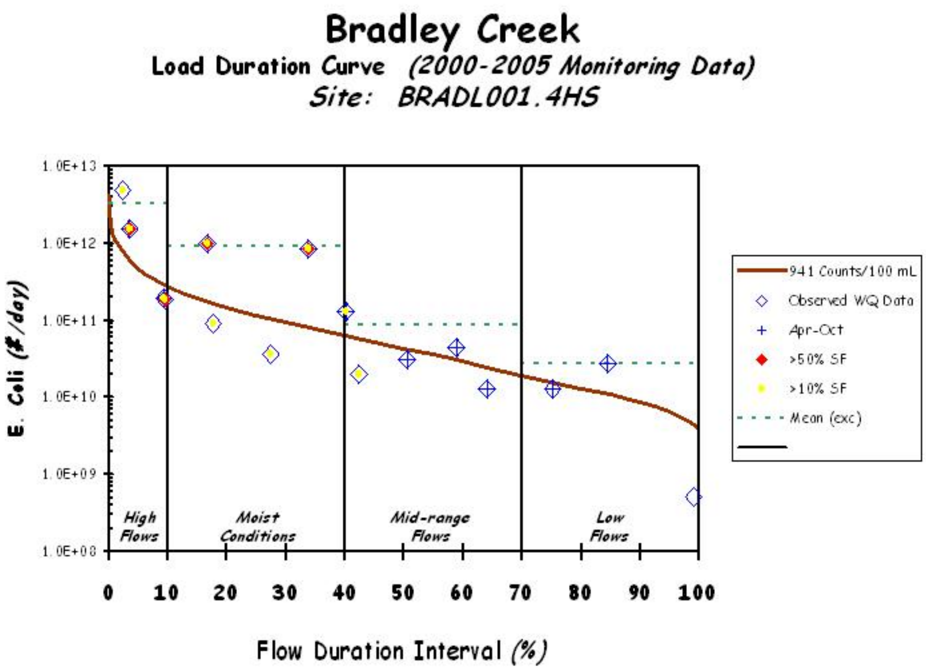

Figure E-10. E. Coli Load Duration Curve for Bradley Creek – RM1.4

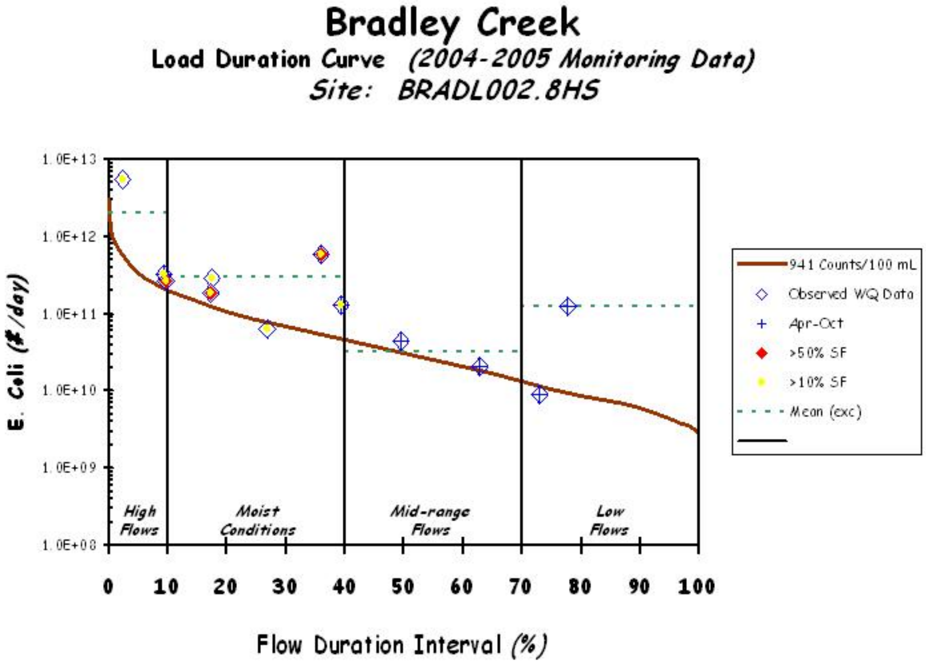

Figure E-11. E. Coli Load Duration Curve for Bradley Creek – RM2.8

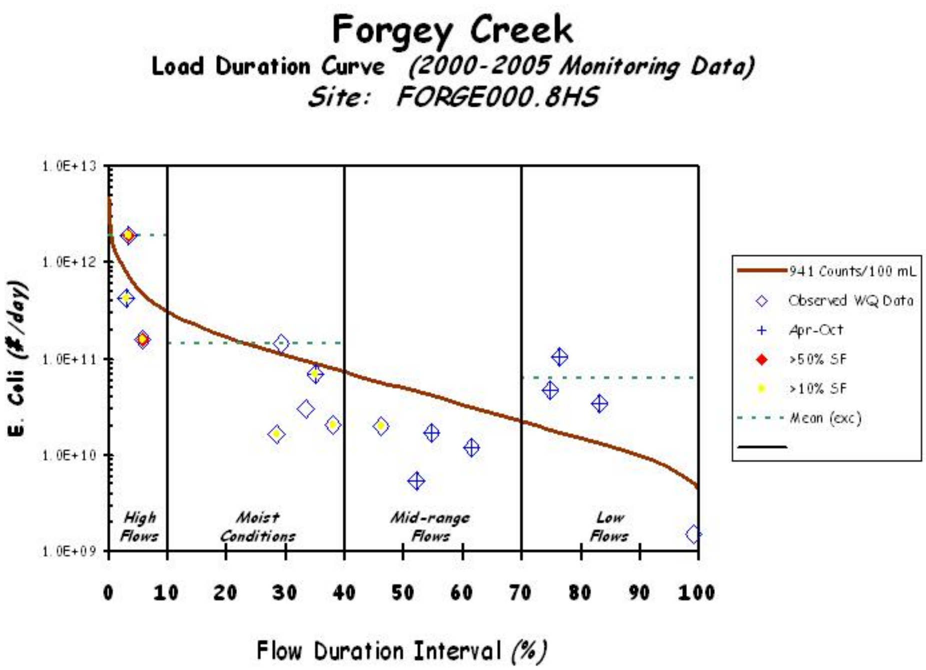

Figure E-12. E. Coli Load Duration Curve for Forgey Creek

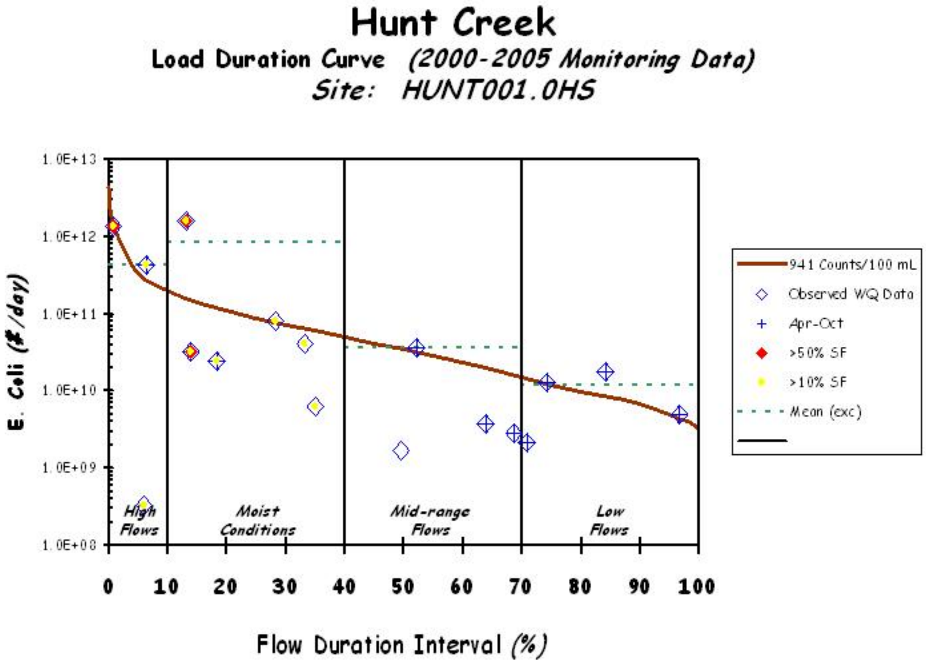

Figure E-13. E. Coli Load Duration Curve for Hunt Creek

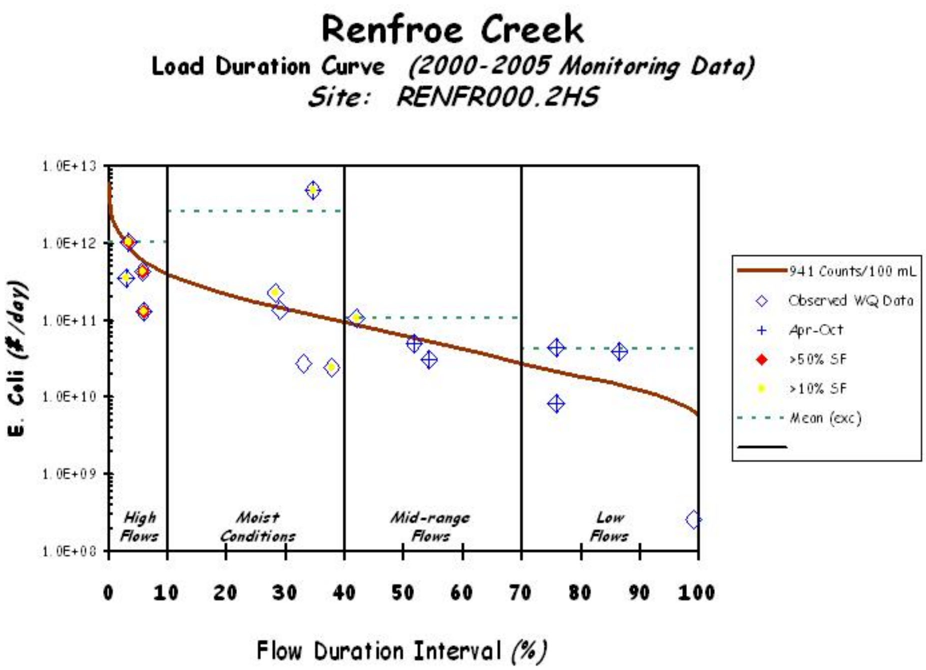

Figure E-14. E. Coli Load Duration Curve for Renfroe Creek – RM0.2

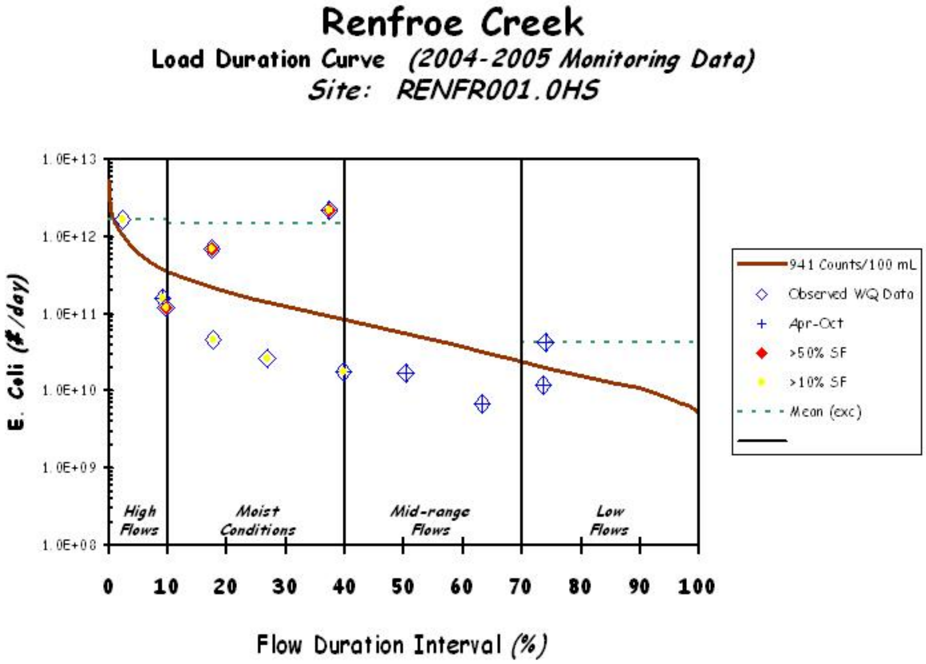

Figure E-15. E. Coli Load Duration Curve for Renfroe Creek – RM1.0

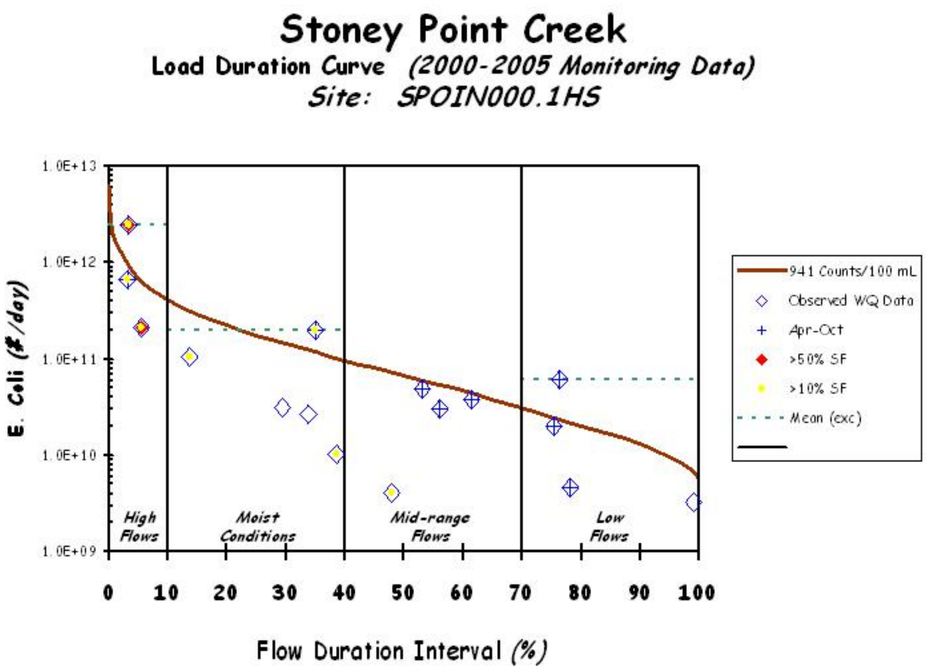

Figure E-16. E. Coli Load Duration Curve for Stoney Point Creek

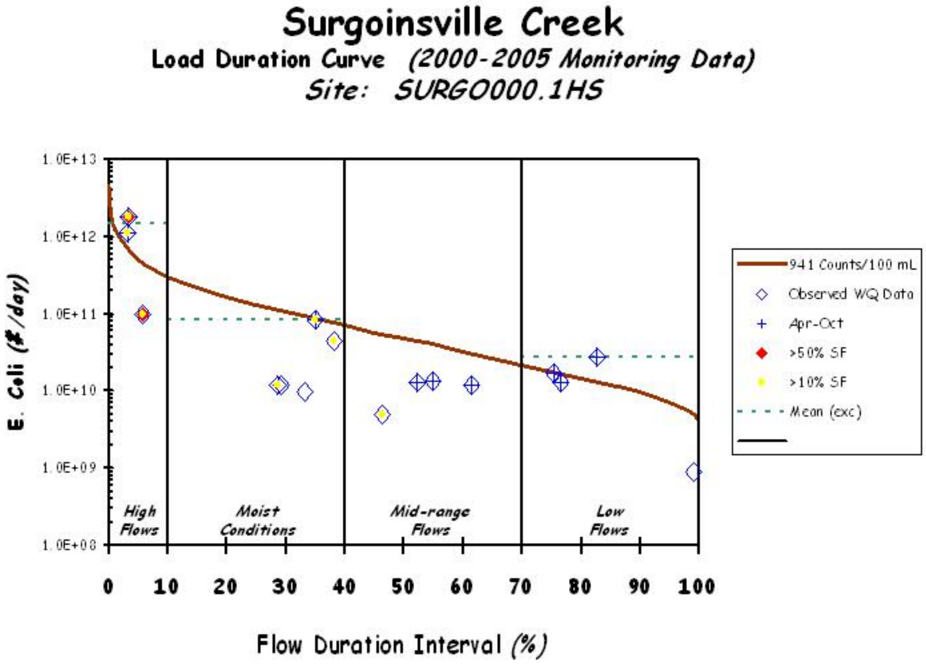

Figure E-17. E. Coli Load Duration Curve for Surgoinsville Creek

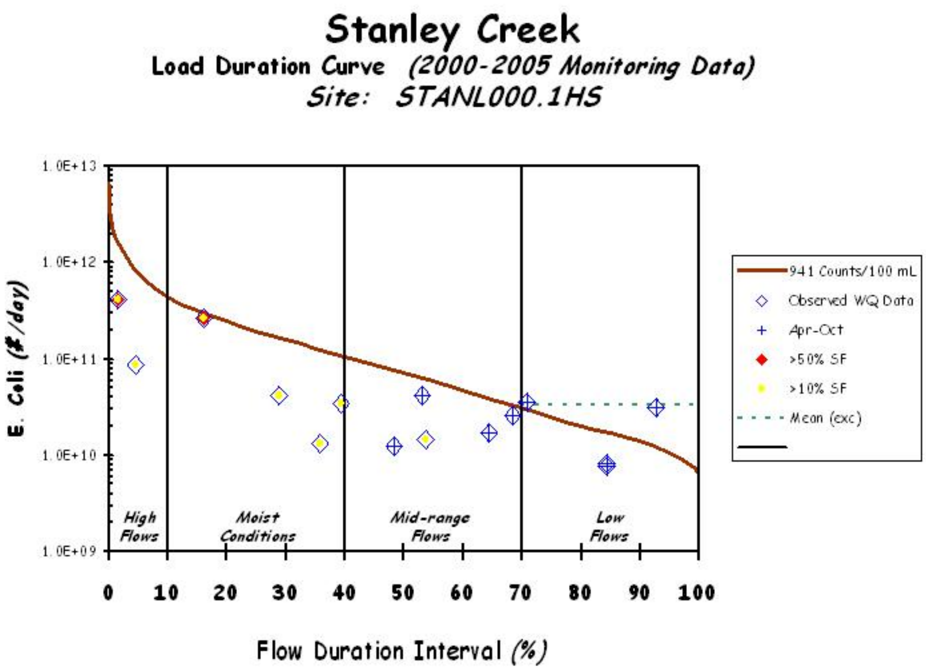

Figure E-18. E. Coli Load Duration Curve for Stanley Creek

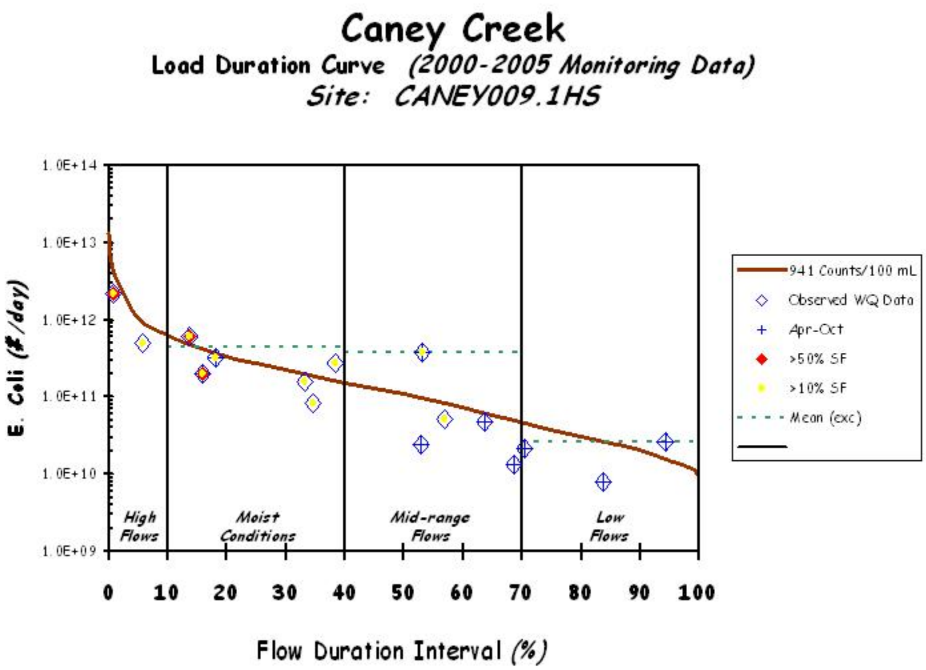

Figure E-19. E. Coli Load Duration Curve for Caney Creek

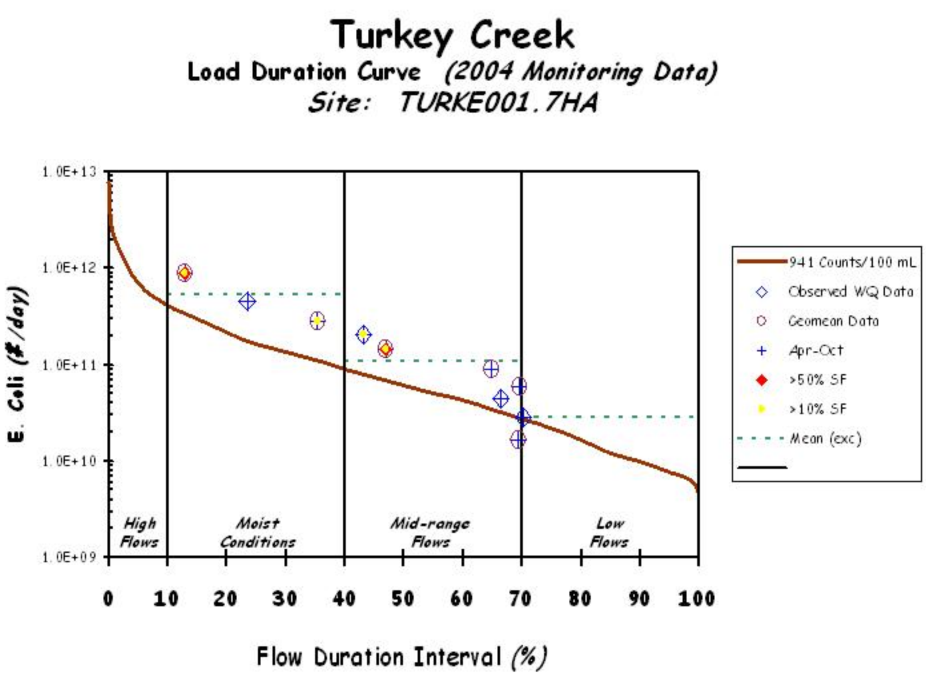

Figure E-20. E. Coli Load Duration Curve for Turkey Creek

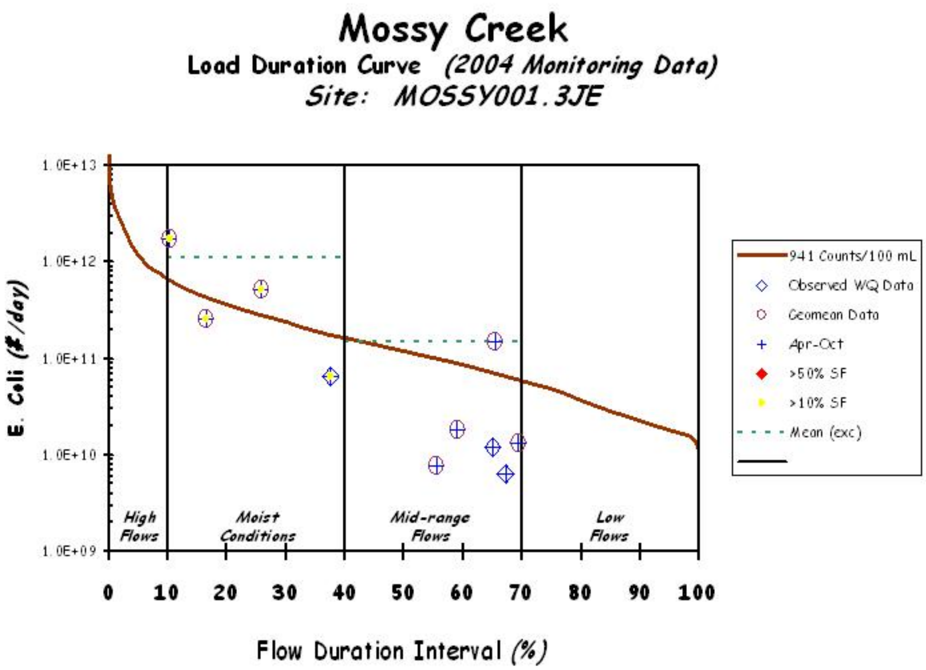

Figure E-21. E. Coli Load Duration Curve for Mossy Creek

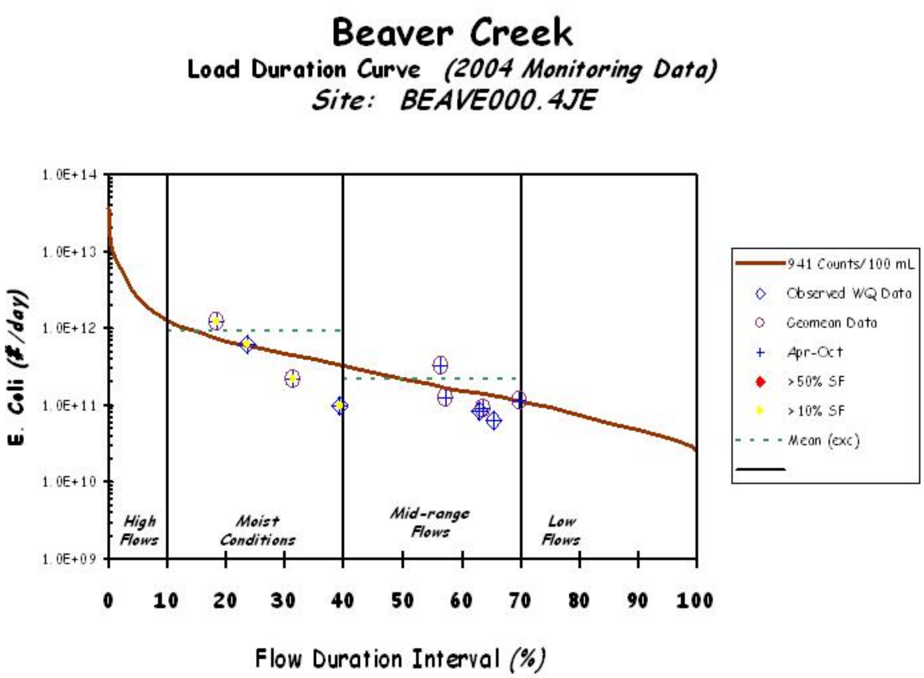

Figure E-22. E. Coli Load Duration Curve for Beaver Creek

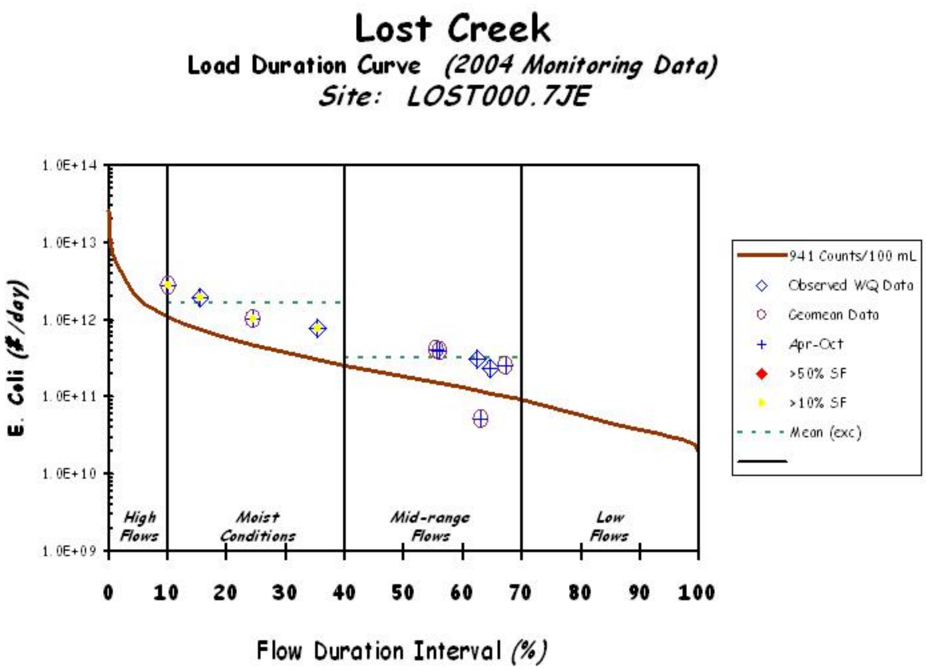

Figure E-23. E. Coli Load Duration Curve for Lost Creek – RM0.7

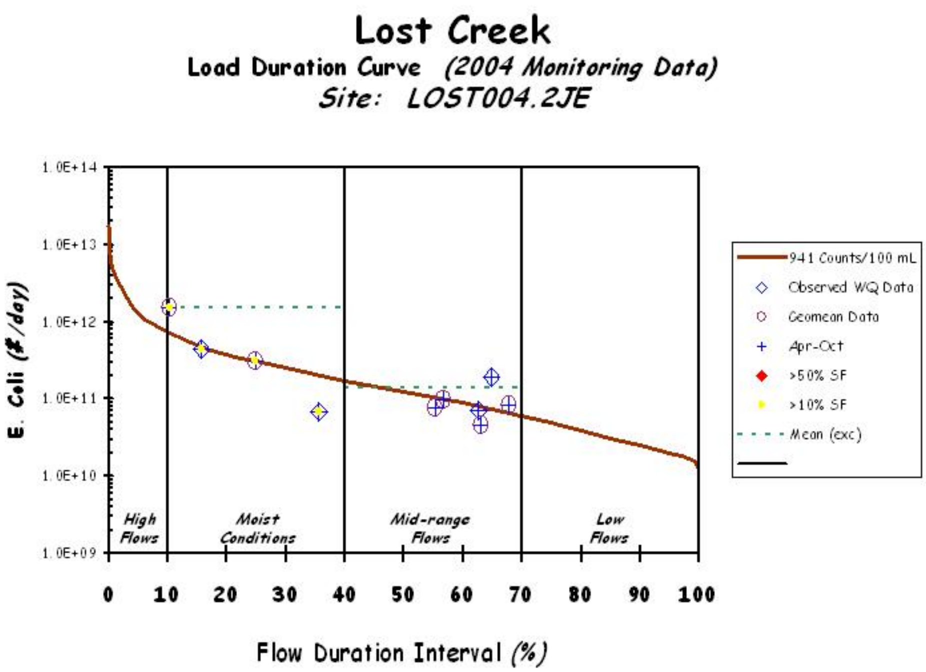

Figure E-24. E. Coli Load Duration Curve for Lost Creek – RM4.2

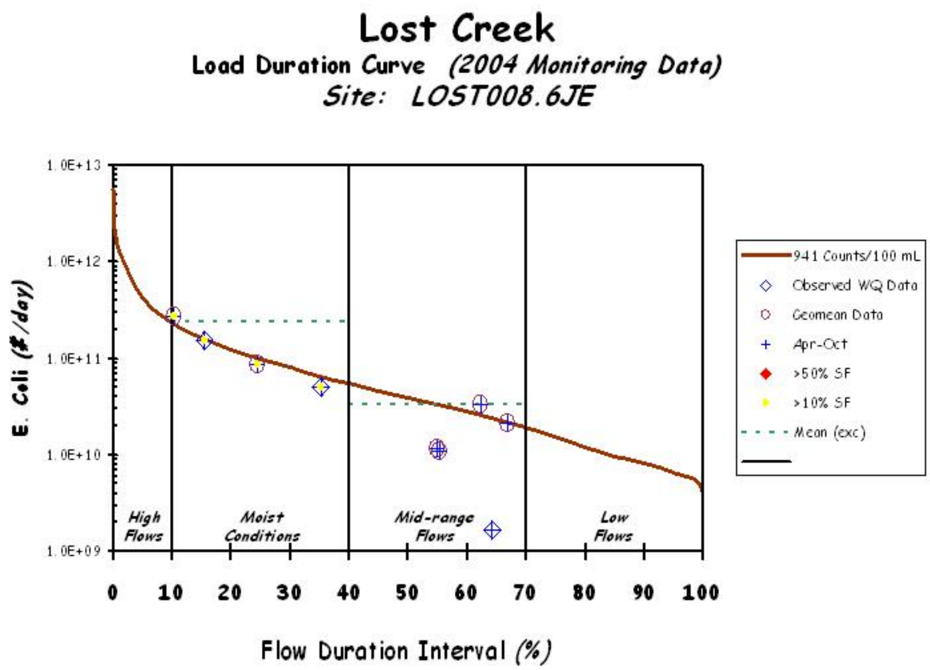

Figure E-25. E. Coli Load Duration Curve for Lost Creek – RM8.6

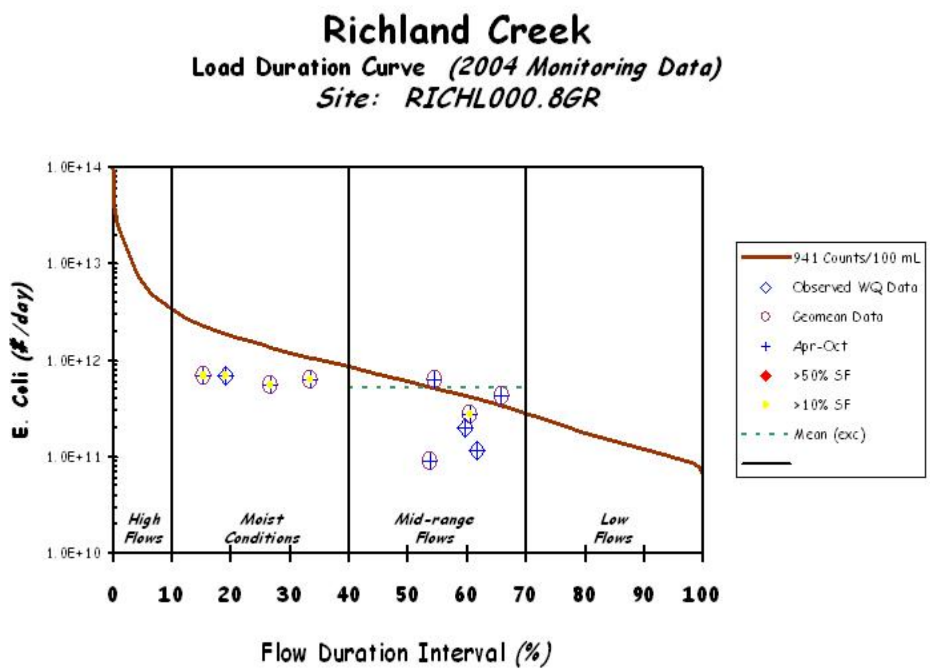

Figure E-26. E. Coli Load Duration Curve for Richland Creek – RM0.8

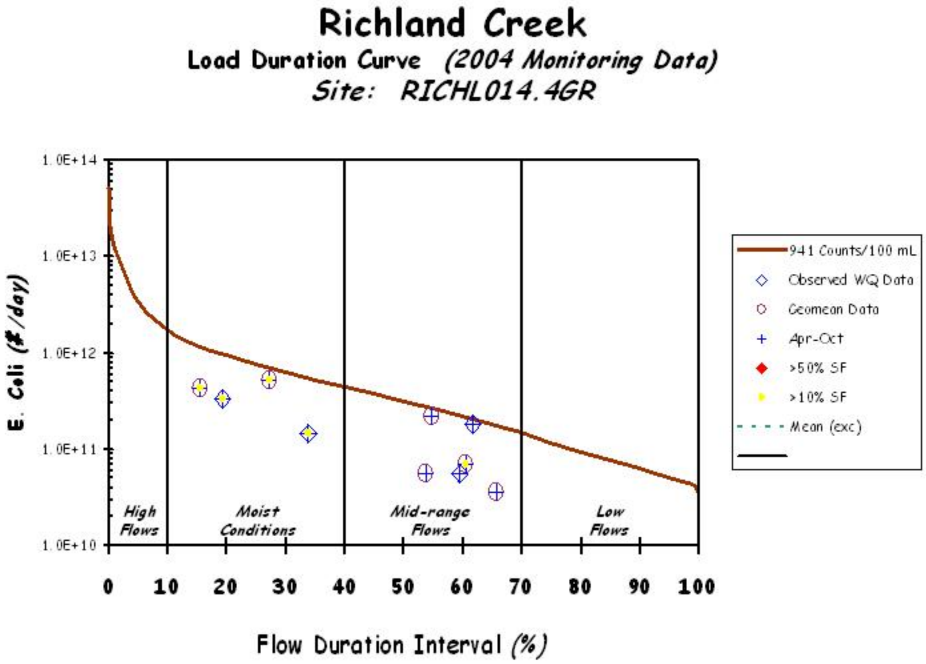

Figure E-27. E. Coli Load Duration Curve for Richland Creek – RM14.4

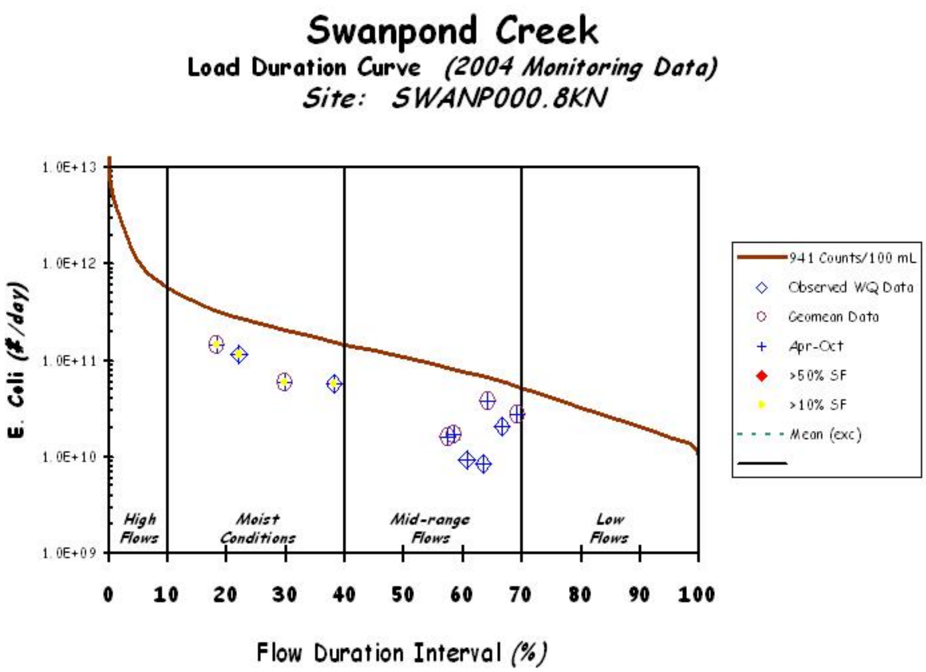

Figure E-28. E. Coli Load Duration Curve for Swanpond Creek

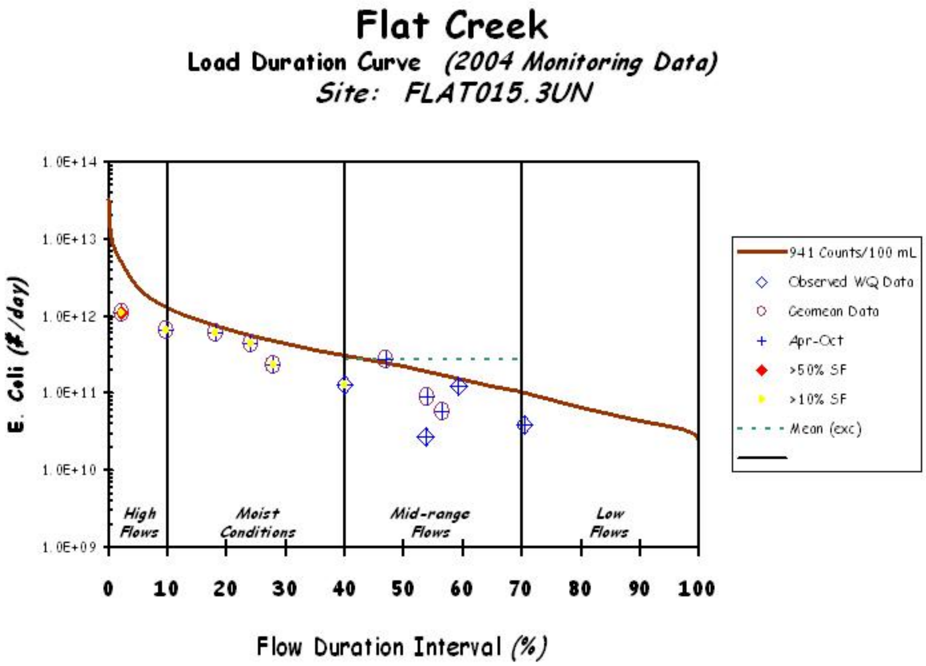

Figure E-29. E. Coli Load Duration Curve for Flat Creek

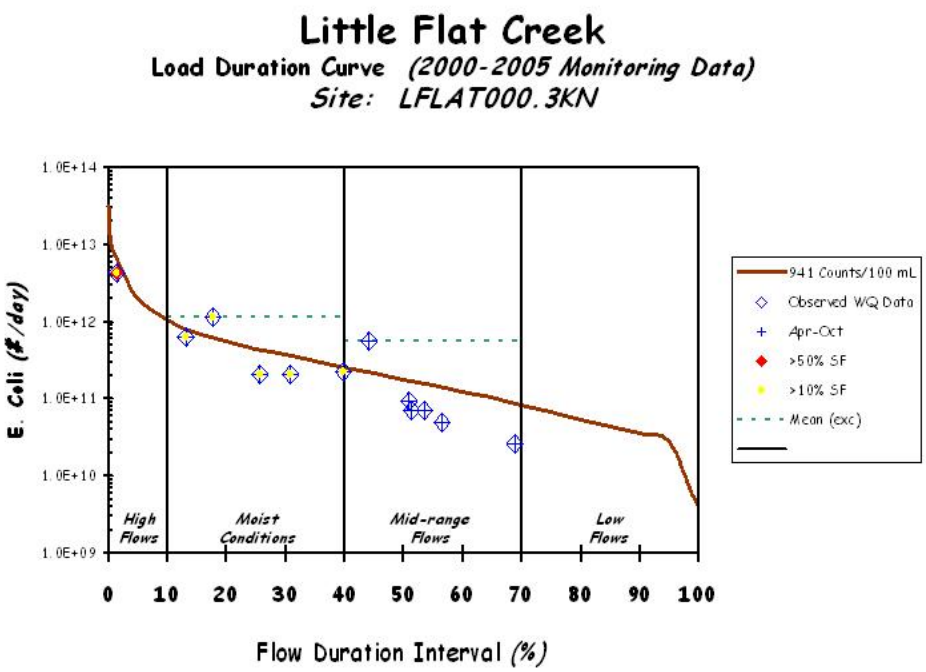

Figure E-30. E. Coli Load Duration Curve for Little Flat Creek

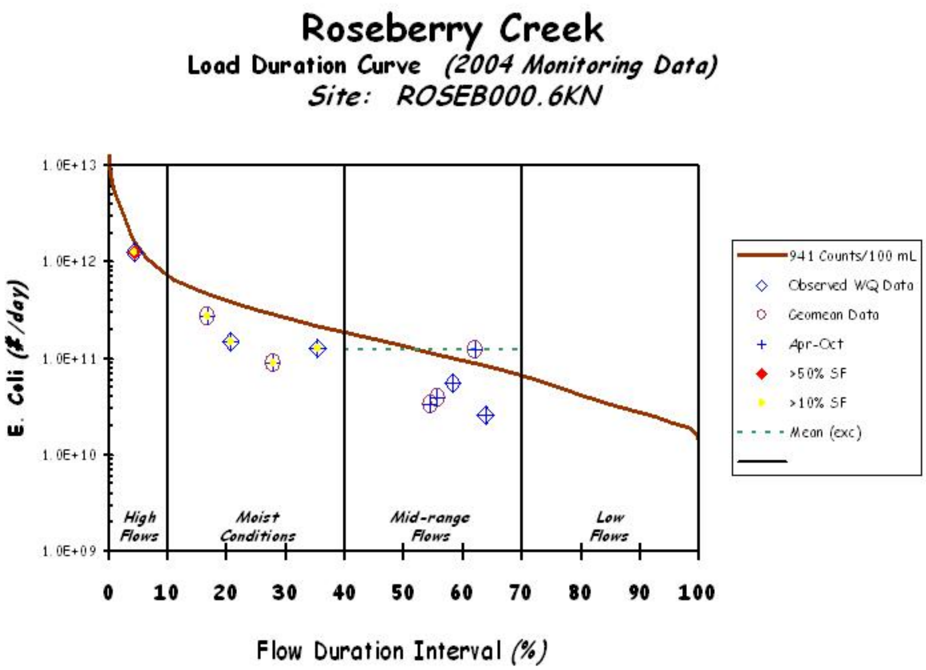

Figure E-31. E. Coli Load Duration Curve for Roseberry Creek

Table E-4. Calculated Load Reduction Based on Daily Loading – Alexander Creek – RM0.6

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	65.39	3.0%	299	4.78E+11	NR	**9.9**	**11.4**
5/24/00		62.51	3.3%	1553	2.38E+12	**39.4**		
2/23/05		40.82	5.7%	100	9.99E+10	NR		
6/8/05		40.00	5.9%	548	5.36E+11	NR		
1/19/05	Moist Conditions	10.77	28.6%	137	3.61E+10	NR	**NR**	**NR**
3/16/05		10.62	29.1%	740	1.92E+11	NR		
12/20/04		8.86	33.8%	70	1.52E+10	NR		
7/28/04		8.78	34.1%	461	9.90E+10	NR		
11/18/04		7.46	38.6%	133	2.43E+10	NR		
2/23/00	Mid-Range Flows	6.42	43.5%	26	4.09E+09	NR	**NR**	**NR**
4/21/05		4.81	53.2%	365	4.30E+10	NR		
5/17/05		4.47	56.0%	172	1.88E+10	NR		
9/9/04	Low Flows	2.58	75.3%	740	4.68E+10	NR	**15.3**	**16.2**
8/24/00		2.50	76.5%	2419	1.48E+11	**61.1**		
8/18/04		2.39	78.3%	410	2.40E+10	NR		
11/2/00		1.42	99.3%	131	4.56E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-5. Calculated Load Reduction Based on Daily Loading – Alexander Creek – RM1.4

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
10/20/04	High Flows	60.07	2.9%	740	1.09E+12	NR		
5/24/00		57.28	3.2%	1732.87	2.43E+12	**45.7**		
2/23/05		36.35	5.8%	411	3.66E+11	NR		
6/8/05		35.63	6.1%	1100	9.59E+11	**14.5**	**15.0**	**18.5**
1/19/05	Moist Conditions	9.96	28.2%	630	1.54E+11	NR		
3/16/05		9.60	29.1%	1300	3.05E+11	**27.6**		
12/20/04		8.21	33.1%	613	1.23E+11	NR		
7/28/04		8.05	33.7%	727	1.43E+11	NR		
11/18/04		6.93	38.1%	1986	3.37E+11	**52.6**	**16.0**	**18.4**
2/23/00	Mid-Range Flows	5.98	42.6%	64	9.37E+09	NR		
4/21/05		4.50	52.2%	613	6.75E+10	NR		
5/17/05		4.18	54.9%	740	7.58E+10	NR	**NR**	**NR**
9/9/04	Low Flows	2.45	74.1%	613	3.67E+10	NR		
8/18/04		2.27	77.2%	1320	7.34E+10	**28.7**		
8/24/00		2.11	80.4%	2419	1.25E+11	**61.1**		
11/2/00		1.39	99.3%	308	1.05E+10	NR	**22.5**	**25.2**

Note: NR = No reduction required
NA = Not applicable

Table E-6. Calculated Load Reduction Based on Daily Loading – Hord Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	43.37	2.9%	345	3.66E+11	NR	**6.9**	**8.7**
5/24/00		40.81	3.3%	1300	1.30E+12	**27.6**		
2/23/05		25.25	6.1%	310	1.92E+11	NR		
6/8/05		24.70	6.4%	770	4.65E+11	NR		
1/19/05	Moist Conditions	6.57	27.9%	400	6.43E+10	NR	**NR**	**NR**
3/15/05		6.41	28.6%	96	1.51E+10	NR		
12/20/04		5.28	33.0%	100	1.29E+10	NR		
7/28/04		4.90	34.8%	816	9.78E+10	NR		
11/18/04		4.38	37.4%	133	1.43E+10	NR		
2/23/00	Mid-Range Flows	3.75	41.4%	50	4.59E+09	NR	**NR**	**2.7**
4/21/05		2.56	51.4%	921	5.76E+10	NR		
5/17/05		2.33	53.9%	310	1.76E+10	NR		
8/18/04	Low Flows	0.94	74.6%	310	7.13E+09	NR	**NR**	**NR**
9/9/04		0.92	75.1%	201	4.50E+09	NR		
11/20/00		0.51	89.9%	127	1.60E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-7. Calculated Load Reduction Based on Daily Loading – Smith Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
8/24/00	High Flows	10.80	4.7%	2419	6.39E+11	**61.1**	**16.3**	**19.6**
7/28/04		10.20	5.0%	770	1.92E+11	NR		
6/8/05		9.01	5.9%	980	2.16E+11	**4.0**		
10/20/04		7.14	8.2%	300	5.24E+10	NR		
3/15/05	Moist Conditions	2.39	29.1%	200	1.17E+10	NR	**NR**	**NR**
1/19/05		2.27	30.6%	28	1.56E+09	NR		
12/20/04		2.01	34.3%	100	4.93E+09	NR		
2/23/05		1.80	37.9%	18	7.93E+08	NR		
4/21/05		1.73	39.4%	119	5.02E+09	NR		
5/17/05	Mid-Range Flows	1.59	42.0%	200	7.77E+09	NR	**3.6**	**4.9**
5/24/00		1.37	46.8%	1203.3	4.03E+10	**21.8**		
11/18/04		1.33	47.8%	36	1.17E+09	NR		
2/23/00		1.28	49.2%	14	4.37E+08	NR		
8/18/04		0.95	59.0%	200	4.63E+09	NR		
9/9/04		0.80	63.6%	620	1.22E+10	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-8. Calculated Load Reduction Based on Daily Loading – Bradley Creek – RM0.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/12/05	High Flows	92.54	2.4%	4790	1.08E+13	**80.4**		
10/14/04		36.12	9.3%	1320	1.17E+12	**28.7**		
2/16/05		34.89	9.7%	387	3.30E+11	NR	**36.4**	**39.4**
3/23/05	Moist Conditions	21.54	17.2%	1350	7.11E+11	**30.3**		
12/16/04		20.75	17.7%	310	1.57E+11	NR		
11/16/04		13.28	27.4%	816	2.65E+11	NR		
7/27/04		10.50	32.9%	57940	1.49E+13	**98.4**	**32.2**	**33.9**
4/18/05	Mid-Range Flows	7.80	40.2%	488	9.31E+10	NR		
5/11/05		5.25	51.2%	1300	1.67E+11	**27.6**		
9/8/04		4.96	52.6%	5380	6.53E+11	**82.5**		
6/21/05		3.05	64.9%	3680	2.75E+11	**74.4**	**46.1**	**49.0**
8/17/04	Low Flows	1.92	76.0%	1733	8.15E+10	**45.7**	**45.7**	**51.1**

Note: NR = No reduction required
NA = Not applicable

Table E-9. Calculated Load Reduction Based on Daily Loading – Bradley Creek – RM1.4

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/12/05	High Flows	31.94	2.4%	6270	4.90E+12	**85.0**		
5/24/00		26.16	3.5%	2419	1.55E+12	**61.1**		
10/14/04		12.55	9.4%	630	1.93E+11	NR		
2/16/05		12.27	9.6%	630	1.89E+11	NR	**36.5**	**37.9**
3/23/05	Moist Conditions	7.60	16.8%	5290	9.84E+11	**82.2**		
12/16/04		7.24	17.7%	520	9.22E+10	NR		
11/16/04		4.62	27.4%	326	3.69E+10	NR		
7/27/04		3.52	33.8%	9870	8.51E+11	**90.5**	**43.2**	**43.9**
4/18/05	Mid-Range Flows	2.72	40.2%	1970	1.31E+11	**52.2**		
2/23/00		2.49	42.5%	326	1.99E+10	NR		
5/11/05		1.84	50.6%	687	3.10E+10	NR		
9/8/04		1.32	59.0%	1350	4.37E+10	**30.3**		
6/21/05		1.07	64.1%	488	1.28E+10	NR	**16.5**	**18.9**
8/17/04	Low Flows	0.68	75.2%	770	1.27E+10	NR		
8/24/00		0.47	84.7%	2419	2.79E+10	**61.1**		
11/2/00		0.20	99.3%	108	5.16E+08	NR	**20.4**	**21.7**

Note: NR = No reduction required
NA = Not applicable

Table E-10. Calculated Load Reduction Based on Daily Loading – Bradley Creek – RM2.8

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/12/05	High Flows	23.67	2.4%	9340	5.41E+12	**89.9**	**48.5**	**53.7**
10/14/04		9.31	9.3%	1414	3.22E+11	**33.5**		
2/16/05		8.95	9.7%	1210	2.65E+11	**22.2**		
3/23/05	Moist Conditions	5.46	17.3%	1414	1.89E+11	**33.5**	**49.2**	**52.3**
12/16/04		5.38	17.5%	2230	2.94E+11	**57.8**		
11/16/04		3.42	26.9%	770	6.44E+10	NR		
7/27/04		2.32	36.1%	10500	5.96E+11	**91.0**		
4/18/05		2.02	39.5%	2590	1.28E+11	**63.7**		
5/11/05	Mid-Range Flows	1.38	49.7%	1300	4.39E+10	**27.6**	**18.8**	**26.9**
6/21/05		0.80	62.9%	1046	2.05E+10	**10.0**		
8/17/04	Low Flows	0.50	73.2%	740	9.10E+09	NR	**46.2**	**46.5**
9/8/04		0.41	77.8%	12230	1.24E+11	**92.3**		

Note: NR = No reduction required
NA = Not applicable

Table E-11. Calculated Load Reduction Based on Daily Loading – Forgey Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	33.99	3.0%	520	4.32E+11	NR	**20.4**	**21.7**
5/24/00		32.12	3.3%	2419.2	1.90E+12	**61.1**		
2/23/05		20.75	5.8%	310	1.57E+11	NR		
1/19/05	Moist Conditions	5.15	28.4%	130	1.64E+10	NR	**4.3**	**5.9**
3/16/05		4.98	29.3%	1200	1.46E+11	**21.6**		
12/20/04		4.14	33.4%	300	3.04E+10	NR		
7/28/04		3.88	35.1%	727	6.89E+10	NR		
11/18/04		3.44	38.1%	248	2.09E+10	NR		
2/24/00	Mid-Range Flows	2.48	46.3%	328	1.99E+10	NR	**NR**	**NR**
4/21/05		2.01	52.2%	109	5.36E+09	NR		
5/17/05		1.83	54.7%	387	1.73E+10	NR		
6/20/05		1.36	61.6%	365	1.21E+10	NR		
9/9/04	Low Flows	0.79	74.9%	2419	4.70E+10	**61.1**	**51.5**	**53.9**
8/18/04		0.74	76.5%	5880	1.06E+11	**85.6**		
8/24/00		0.58	83.2%	2419	3.40E+10	**61.1**		
11/2/00		0.23	99.3%	272	1.50E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-12. Calculated Load Reduction Based on Daily Loading – Hunt Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/11/05	High Flows	64.71	0.7%	866	1.37E+12	NR	11.2	14.1
12/13/04		13.34	5.9%	1	3.26E+08	NR		
4/5/00		12.45	6.4%	1414	4.31E+11	33.5		
2/3/05	Moist Conditions	6.86	13.1%	9600	1.61E+12	90.2	15.5	17.3
4/12/05		6.49	14.0%	200	3.17E+10	NR		
5/4/05		5.08	18.4%	200	2.48E+10	NR		
11/8/04		3.42	28.2%	970	8.12E+10	3.0		
11/9/04		2.78	33.3%	613	4.17E+10	NR		
3/3/05		2.60	35.1%	100	6.36E+09	NR		
2/2/00	Mid-Range Flows	1.54	49.6%	45	1.69E+09	NR	2.8	5.0
6/2/05		1.41	52.1%	1060	3.65E+10	11.2		
7/21/04		0.86	64.0%	179	3.79E+09	NR		
10/5/04		0.70	68.8%	167	2.85E+09	NR		
8/11/04	Low Flows	0.63	70.9%	140	2.17E+09	NR	16.7	22.5
7/13/00		0.54	74.3%	980	1.30E+10	4.0		
9/1/04		0.37	84.3%	1986	1.81E+10	52.6		
10/5/00		0.19	96.8%	1046	4.88E+09	10.0		

Note: NR = No reduction required
NA = Not applicable

Table E-13. Calculated Load Reduction Based on Daily Loading – Renfroe Creek – RM0.2

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/14/04	High Flows	45.73	3.0%	310	3.47E+11	NR	1.0	3.4
5/24/00		42.36	3.4%	980	1.02E+12	**4.0**		
2/16/05		27.86	5.8%	630	4.29E+11	NR		
6/21/05		27.04	6.0%	200	1.32E+11	NR		
1/12/05	Moist Conditions	6.94	28.2%	1340	2.28E+11	**29.8**	25.5	26.9
3/23/05		6.68	29.1%	816	1.33E+11	NR		
12/16/04		5.61	33.0%	200	2.74E+10	NR		
7/27/04		5.24	34.7%	38730	4.97E+12	**97.6**		
11/16/04		4.63	37.9%	214	2.42E+10	NR		
2/23/00	Mid-Range Flows	3.93	42.0%	1120	1.08E+11	**16.0**	5.3	8.1
4/18/05		2.72	51.8%	740	4.92E+10	NR		
5/11/05		2.47	54.3%	520	3.15E+10	NR		
9/8/04	Low Flows	1.00	75.8%	1850	4.52E+10	**49.1**	27.6	29.8
8/17/04		1.00	75.8%	345	8.42E+09	NR		
8/24/00		0.66	86.6%	2419	3.88E+10	**61.1**		
11/2/00		0.30	99.3%	35	2.61E+08	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-14. Calculated Load Reduction Based on Daily Loading – Renfroe Creek – RM1.0

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/12/05	High Flows	42.56	2.4%	1600	1.67E+12	**41.2**	**13.7**	**15.7**
10/14/04		16.70	9.2%	387	1.58E+11	NR		
2/16/05		15.98	9.7%	310	1.21E+11	NR		
3/23/05	Moist Conditions	9.64	17.6%	2920	6.88E+11	**67.8**	**32.7**	**33.5**
12/16/04		9.61	17.7%	200	4.70E+10	NR		
11/16/04		6.18	26.9%	172	2.60E+10	NR		
7/27/04		3.96	37.5%	22820	2.21E+12	**95.9**		
4/18/05		3.61	39.8%	200	1.77E+10	NR		
5/11/05	Mid-Range Flows	2.42	50.3%	291	1.72E+10	NR	**NR**	**NR**
6/21/05		1.41	63.3%	200	6.90E+09	NR		
8/17/04	Low Flows	0.89	73.7%	548	1.20E+10	NR	**26.3**	**28.7**
9/8/04		0.88	74.2%	1986	4.26E+10	**52.6**		

Note: NR = No reduction required
NA = Not applicable

Table E-15. Calculated Load Reduction Based on Daily Loading – Sinking Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	10.44	3.1%	740	1.89E+11	NR		
5/24/00		9.43	3.6%	2419.2	5.58E+11	**61.1**		
2/23/05		6.82	5.5%	135	2.25E+10	NR	**20.4**	**21.7**
3/16/05	Moist Conditions	1.60	28.6%	100	3.91E+09	NR		
1/19/05		1.59	28.9%	47	1.82E+09	NR		
12/20/04		1.29	33.5%	100	3.15E+09	NR		
7/28/04		1.17	35.9%	980	2.81E+10	**4.0**		
11/18/04		1.06	38.4%	133	3.46E+09	NR	**0.8**	**2.7**
2/24/00	Mid-Range Flows	0.77	46.5%	2419	4.56E+10	**61.1**		
4/21/05		0.62	52.5%	1553	2.36E+10	**39.4**		
5/17/05		0.57	55.1%	310	4.30E+09	NR		
6/20/05		0.43	61.8%	2419	2.53E+10	**61.1**	**40.4**	**43.9**
8/18/04	Low Flows	0.23	76.6%	1580	8.90E+09	**40.4**		
9/9/04		0.23	77.0%	866	4.83E+09	NR		
8/24/00		0.18	83.6%	2419	1.05E+10	**61.1**		
11/2/00		0.07	99.3%	2419	4.15E+09	**61.1**	**40.7**	**44.6**

Note: NR = No reduction required
NA = Not applicable

Table E-16. Calculated Load Reduction Based on Daily Loading – Stoney Point Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	43.80	3.1%	630	6.75E+11	NR		
5/24/00		41.04	3.4%	2419	2.43E+12	**61.1**		
2/23/05		28.10	5.6%	310	2.13E+11	NR	**20.4**	**21.7**
1/19/04	Moist Conditions	13.89	13.7%	313	1.06E+11	NR		
3/15/05		6.45	29.4%	200	3.16E+10	NR		
12/20/04		5.38	33.8%	200	2.63E+10	NR		
7/28/04		5.15	35.0%	1553	1.96E+11	**39.4**		
11/18/04		4.42	38.6%	93	1.01E+10	NR	**7.9**	**9.1**
2/24/00	Mid-Range Flows	3.14	48.0%	53	4.07E+09	NR		
4/21/05		2.61	53.2%	770	4.93E+10	NR		
5/17/05		2.38	56.1%	517	3.01E+10	NR		
6/20/05		1.89	61.6%	816	3.78E+10	NR	**NR**	**NR**
9/9/04	Low Flows	1.09	75.4%	740	1.97E+10	NR		
8/24/00		1.03	76.4%	2419	6.10E+10	**61.1**		
8/18/04		0.95	78.2%	200	4.66E+09	NR		
11/2/00		0.29	99.3%	461	3.28E+09	NR	**15.3**	**16.2**

Note: NR = No reduction required
NA = Not applicable

Table E-17. Calculated Load Reduction Based on Daily Loading – Surgoinsville Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/20/04	High Flows	32.57	3.1%	1420	1.13E+12	**33.7**		
5/24/00		30.15	3.4%	2419	1.78E+12	**61.1**		
2/23/05		20.32	5.7%	200	9.94E+10	NR	**31.6**	**35.1**
1/19/05	Moist Conditions	4.94	28.6%	100	1.21E+10	NR		
3/15/05		4.81	29.2%	100	1.18E+10	NR		
12/20/04		4.00	33.2%	100	9.78E+09	NR		
7/28/04		3.74	35.1%	921	8.42E+10	NR		
11/18/04		3.30	38.2%	548	4.42E+10	NR	**NR**	**1.6**
2/24/00	Mid-Range Flows	2.37	46.5%	84	4.87E+09	NR		
4/21/05		1.94	52.3%	276	1.31E+10	NR		
5/17/05		1.76	54.9%	310	1.34E+10	NR		
6/20/05		1.32	61.5%	365	1.18E+10	NR	**NR**	**NR**
9/9/04	Low Flows	0.75	75.5%	921	1.69E+10	NR		
8/18/04		0.71	76.6%	730	1.27E+10	NR		
8/24/00		0.56	82.9%	1986	2.73E+10	**52.6**		
11/2/00		0.22	99.3%	167	8.86E+08	NR	**13.2**	**16.3**

Note: NR = No reduction required
NA = Not applicable

Table E-18. Calculated Load Reduction Based on Daily Loading – Stanley Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/11/05	High Flows	68.45	1.6%	249	4.17E+11	NR		
12/13/04		35.97	4.5%	98	8.62E+10	NR	**NR**	**NR**
2/3/05	Moist Conditions	13.20	16.2%	816	2.64E+11	NR		
11/9/04		7.19	28.9%	236	4.15E+10	NR		
3/3/05		5.35	35.8%	100	1.31E+10	NR		
3/1/00		4.63	39.5%	308	3.49E+10	NR	**NR**	**NR**
5/4/03	Mid-Range Flows	3.30	48.4%	153	1.24E+10	NR		
6/8/00		2.77	53.2%	613	4.15E+10	NR		
12/20/00		2.71	53.8%	222	1.47E+10	NR		
7/21/04		1.70	64.5%	411	1.71E+10	NR		
10/5/04		1.44	68.5%	727	2.56E+10	NR	**NR**	**NR**
8/11/04	Low Flows	1.30	70.9%	1120	3.56E+10	**16.0**		
9/1/04		0.76	84.4%	411	7.65E+09	NR		
9/1/04		0.76	84.4%	435	8.10E+09	NR		
9/21/00		0.53	92.8%	2419	3.11E+10	**61.1**	**19.3**	**22.3**

Note: NR = No reduction required
NA = Not applicable

Table E-19. Calculated Load Reduction Based on Daily Loading – Crockett Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/11/05	High Flows	57.29	1.3%	172	2.41E+11	NR		
5/24/00		34.50	3.1%	2419	2.04E+12	**61.1**		
12/13/04		22.53	5.6%	461	2.54E+11	NR	**20.4**	**21.7**
2/3/05	Moist Conditions	10.79	14.3%	310	8.19E+10	NR		
4/12/05		9.99	16.0%	520	1.27E+11	NR		
5/4/05		8.32	19.4%	148	3.01E+10	NR		
6/2/05		6.39	25.9%	5290	8.27E+11	**82.2**		
11/9/04		4.51	35.2%	310	3.42E+10	NR	**16.4**	**16.8**
3/3/05	Mid-Range Flows	3.36	43.1%	100	8.23E+09	NR		
2/24/00		2.22	54.3%	50	2.72E+09	NR		
8/24/00		2.19	54.7%	2419	1.30E+11	**61.1**	**20.4**	**21.7**
7/21/04	Low Flows	1.07	72.1%	108	2.81E+09	NR		
10/5/04		0.92	75.1%	291	6.58E+09	NR		
8/11/04		0.87	76.2%	214	4.54E+09	NR		
9/1/04		0.49	88.2%	299	3.57E+09	**52.6**		
11/2/00		0.21	99.3%	44	2.28E+08	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-20. Calculated Load Reduction Based on Daily Loading – Caney Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/11/05	High Flows	185.27	0.8%	488	2.21E+12	NR	**NR**	**NR**
12/13/04		42.30	5.8%	488	5.05E+11	NR		
2/3/05	Moist Conditions	20.62	13.8%	1220	6.16E+11	**22.9**	**10.4**	**15.2**
4/12/05		18.05	16.0%	461	2.04E+11	NR		
5/4/05		16.15	18.1%	830	3.28E+11	NR		
11/9/04		8.75	33.2%	740	1.58E+11	NR		
3/3/05		8.19	34.7%	410	8.21E+10	NR		
3/1/00		7.16	38.5%	1553	2.72E+11	**39.4**		
6/8/00	Mid-Range Flows	4.25	52.9%	236	2.45E+10	NR	**14.9**	**15.4**
6/2/05		4.18	53.2%	3680	3.76E+11	**74.4**		
12/20/00		3.58	57.0%	579	5.07E+10	NR		
7/21/04		2.69	63.8%	727	4.79E+10	NR		
10/5/04		2.16	68.7%	249	1.31E+10	NR		
8/11/04	Low Flows	1.98	70.5%	435	2.11E+10	NR	**13.1**	**15.2**
9/1/04		1.16	83.9%	276	7.82E+09	NR		
9/21/00		0.69	94.5%	1553	2.62E+10	**39.4**		

Note: NR = No reduction required
NA = Not applicable

Table E21. Calculated Load Reduction Based on Daily Loading – Turkey Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	14.88	12.9%	2419	8.80E+11	**61.1**		
6/29/04		7.76	23.5%	2419	4.59E+11	**61.1**		
8/3/04		4.78	35.4%	2419	2.83E+11	**61.1**	**61.1**	**65.0**
9/22/04	Mid-Range Flows	3.42	43.2%	2419	2.03E+11	**61.1**		
8/11/04		2.96	47.1%	1986	1.44E+11	**52.6**		
7/20/04		1.52	64.9%	2419	8.98E+10	**61.1**		
10/1/04		1.41	66.5%	1300	4.49E+10	**27.6**		
8/26/04		1.22	69.5%	548	1.64E+10	NR		
8/17/04		1.20	69.8%	1986	5.85E+10	**52.6**	**42.5**	**46.6**
10/7/04	Low Flows	1.17	70.3%	980	2.80E+10	**4.0**	**4.0**	**13.6**

Note: NR = No reduction required
NA = Not applicable

Table E-22. Calculated Load Reduction Based on Geomean Data – Turkey Creek

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	1.52	64.9%	2419			
7/29/04	14.88	12.9%	2419			
8/3/04	4.78	35.4%	2419			
8/11/04	2.96	47.1%	1986			
8/17/04	1.20	69.8%	1986	2235.49	**94.4**	**95.0**
8/26/04	1.22	69.5%	548	1661.12	92.4	93.2

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-23. Calculated Load Reduction Based on Daily Loading – Mossy Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	28.83	10.3%	2419	1.71E+12	**61.1**		
6/29/04		18.91	16.5%	548	2.54E+11	NR		
8/3/04		12.04	25.9%	1733	5.10E+11	**45.7**		
9/22/04		7.82	37.6%	345	6.60E+10	NR	**26.7**	**29.0**
8/11/04	Mid-Range Flows	4.35	55.5%	73	7.78E+09	NR		
7/20/04		3.86	59.1%	192	1.81E+10	NR		
10/4/04		3.10	65.2%	157	1.19E+10	NR		
8/17/04		3.04	65.5%	1986	1.48E+11	**52.6**		
10/7/04		2.84	67.4%	91	6.32E+09	NR		
8/26/04		2.59	69.5%	206	1.31E+10	NR	**8.8**	**9.6**

Note: NR = No reduction required
NA = Not applicable

Table E24. Calculated Load Reduction Based on Geomean Data – Mossy Creek

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	3.86	59.1%	192			
7/29/04	28.83	10.3%	2419			
8/3/04	12.04	25.9%	1733			
8/11/04	4.35	55.5%	73			
8/17/04	3.04	65.5%	1986	650.74	80.6	82.6
8/26/04	2.59	69.5%	206	659.96	**80.9**	**82.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-25. Calculated Load Reduction Based on Daily Loading – Beaver Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	32.49	18.3%	1553	1.23E+12	**39.4**		
6/29/04		26.38	23.6%	980	6.33E+11	**4.0**		
8/3/04		19.84	31.3%	461	2.24E+11	NR		
9/22/04		14.72	39.3%	276	9.94E+10	NR	**10.8**	**14.8**
7/20/04	Mid-Range Flows	7.77	56.4%	1732	3.29E+11	**45.7**		
8/11/04		7.48	57.3%	687	1.26E+11	NR		
10/4/04		6.18	63.0%	548	8.29E+10	NR		
8/17/04		6.06	63.7%	613	9.09E+10	NR		
10/7/04		5.69	65.5%	461	6.41E+10	NR		
8/26/04		4.91	69.8%	980	1.18E+11	**4.0**	**8.3**	**10.8**

Note: NR = No reduction required
NA = Not applicable

Table E-26. Calculated Load Reduction Based on Geomean Data – Beaver Creek

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	7.77	56.4%	1732			
7/29/04	32.49	18.3%	1553			
8/3/04	19.84	31.3%	461			
8/11/04	7.48	57.3%	687			
8/17/04	6.06	63.7%	613	878.15	**85.7**	**87.1**
8/26/04	4.91	69.8%	980	783.62	83.9	85.6

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-27. Calculated Load Reduction Based on Daily Loading – Lost Creek – RM0.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	47.64	10.2%	2419	2.82E+12	**61.1**		
6/29/04		32.45	15.6%	2419	1.92E+12	**61.1**		
8/3/04		20.69	24.5%	1986	1.01E+12	**52.6**		
9/22/04		13.33	35.4%	2419	7.89E+11	**61.1**	**59.0**	**63.1**
8/11/04	Mid-Range Flows	6.81	55.5%	2419	4.03E+11	**61.1**		
7/20/04		6.65	56.2%	2419	3.94E+11	**61.1**		
10/4/04		5.32	62.6%	2419	3.15E+11	**61.1**		
8/17/04		5.24	63.1%	400	5.13E+10	NR		
10/7/04		4.88	64.8%	1986	2.37E+11	**52.6**		
8/26/04		4.37	67.4%	2419	2.59E+11	**61.1**	**49.5**	**52.9**

Note: NR = No reduction required
NA = Not applicable

Table E-28. Calculated Load Reduction Based on Geomean Data – Lost Creek – RM0.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	6.65	56.2%	2419			
7/29/04	47.64	10.2%	2419			
8/3/04	20.69	24.5%	1986			
8/11/04	6.81	55.5%	2419			
8/17/04	5.24	63.1%	400	1622.52	**92.2**	**93.0**
8/26/04	4.37	67.4%	2419	1622.52	**92.2**	**93.0**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-29. Calculated Load Reduction Based on Daily Loading – Lost Creek – RM4.2

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
7/29/04	Moist Conditions	31.15	10.3%	1986	1.51E+12	**52.6**		
6/29/04		21.12	15.8%	866	4.48E+11	NR		
8/3/04		13.48	24.9%	921	3.04E+11	NR		
9/22/04		8.68	35.6%	326	6.92E+10	NR	**13.2**	**16.9**
8/11/04	Mid-Range Flows	4.59	55.3%	687	7.71E+10	NR		
7/20/04		4.37	56.7%	921	9.85E+10	NR		
10/4/04		3.50	62.8%	816	6.98E+10	NR		
8/17/04		3.45	63.2%	548	4.62E+10	NR		
10/7/04		3.21	65.0%	2419	1.90E+11	**61.1**		
8/26/04		2.86	68.0%	1203	8.42E+10	**21.8**	**13.8**	**17.1**

Note: NR = No reduction required
NA = Not applicable

Table E-30. Calculated Load Reduction Based on Geomean Data – Lost Creek – RM4.2

Sample Date	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Geometric Mean [CFU/100 ml]	Calculated Reduction to Target GM (126 CFU/100 ml) [%]	Calculated Reduction to Target – MOS (113 CFU/100 ml) [%]
7/20/04	4.37	56.7%	921			
7/29/04	31.15	10.3%	1986			
8/3/04	13.48	24.9%	921			
8/11/04	4.59	55.3%	687			
8/17/04	3.45	63.2%	548	912.95	86.2	87.6
8/26/04	2.86	68.0%	1203	963.05	**86.9**	**88.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-31. Calculated Load Reduction Based on Daily Loading – Lost Creek – RM8.6

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
7/29/04	Moist Conditions	10.09	10.3%	1120	2.77E+11	**16.0**		
6/29/04		6.93	15.6%	921	1.56E+11	NR		
8/3/04		4.41	24.5%	816	8.80E+10	NR		
9/22/04		2.84	35.2%	727	5.06E+10	NR	**4.0**	**8.1**
8/11/04	Mid-Range Flows	1.45	54.9%	326	1.16E+10	NR		
7/20/04		1.43	55.4%	308	1.08E+10	NR		
10/4/04		1.14	62.0%	32	8.96E+08	NR		
8/17/04		1.13	62.3%	1203	3.32E+10	**21.8**		
10/7/04		1.05	64.3%	65	1.67E+09	NR		
8/26/04		0.94	67.0%	929	2.13E+10	NR	**3.6**	**6.4**

Note: NR = No reduction required
NA = Not applicable

Table E-32. Calculated Load Reduction Based on Geomean Data – Lost Creek – RM8.6

Sample Date	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Geometric Mean [CFU/100 ml]	Calculated Reduction to Target GM (126 CFU/100 ml) [%]	Calculated Reduction to Target – MOS (113 CFU/100 ml) [%]
7/20/04	1.43	55.4%	308			
7/29/04	10.09	10.3%	1120			
8/3/04	4.41	24.5%	816			
8/11/04	1.45	54.9%	326			
8/17/04	1.13	62.3%	1203	643.56	80.4	82.4
8/26/04	0.94	67.0%	929	802.57	**84.3**	**85.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-33. Calculated Load Reduction Based on Daily Loading – Richland Creek – RM0.8

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
7/29/04	Moist Conditions	100.27	15.3%	285	6.99E+11	NR	**NR**	**NR**
6/29/04		82.97	19.1%	345	7.00E+11	NR		
8/3/04		60.16	26.6%	378	5.56E+11	NR		
9/22/04		46.44	33.5%	548	6.23E+11	NR		
7/20/04	Mid-Range Flows	23.24	53.7%	157	8.93E+10	NR	**6.3**	**9.0**
8/11/04		22.61	54.5%	1120	6.20E+11	**16.0**		
10/4/04		18.77	59.7%	435	2.00E+11	NR		
8/17/04		18.20	60.6%	613	2.73E+11	NR		
10/7/04		17.28	61.7%	272	1.15E+11	NR		
8/26/04		14.69	65.9%	1203	4.32E+11	**21.8**		

Note: NR = No reduction required
NA = Not applicable

Table E-34. Calculated Load Reduction Based on Geomean Data – Richland Creek – RM0.8

Sample Date	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Geometric Mean [CFU/100 ml]	Calculated Reduction to Target GM (126 CFU/100 ml) [%]	Calculated Reduction to Target – MOS (113 CFU/100 ml) [%]
7/20/04	23.24	53.7%	157			
7/29/04	100.27	15.3%	285			
8/3/04	60.16	26.6%	378			
8/11/04	22.61	54.5%	1120			
8/17/04	18.20	60.6%	613	410.19	69.3	72.5
8/26/04	14.69	65.9%	1203	616.39	**79.6**	**81.7**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-35. Calculated Load Reduction Based on Daily Loading – Richland Creek – RM14.4

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	50.33	15.6%	345	4.25E+11	NR		
6/29/04		42.14	19.4%	326	3.36E+11	NR		
8/3/04		30.54	27.2%	687	5.13E+11	NR		
9/22/04		23.58	33.9%	249	1.44E+11	NR	**NR**	**NR**
7/20/04	Mid-Range Flows	12.02	53.7%	190	5.59E+10	NR		
8/11/04		11.66	54.8%	770	2.20E+11	NR		
10/1/04		9.74	59.6%	238	5.67E+10	NR		
8/14/04		9.41	60.5%	299	6.89E+10	NR		
10/7/04		8.96	61.8%	816	1.79E+11	NR		
8/26/04		7.60	65.8%	192	3.57E+10	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-36. Calculated Load Reduction Based on Geomean Data – Richland Creek – RM14.4

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	12.02	53.7%	190			
7/29/04	50.33	15.6%	345			
8/3/04	30.54	27.2%	687			
8/11/04	11.66	54.8%	770			
8/17/04	9.41	60.5%	299	400.99	68.6	71.8
8/26/04	7.60	65.8%	192	401.84	**68.6**	**71.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-37. Calculated Load Reduction Based on Daily Loading – Swanpond Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/29/04	Moist Conditions	14.33	18.3%	411	1.44E+11	NR		
6/29/04		12.08	22.2%	387	1.14E+11	NR		
8/3/04		8.90	29.9%	272	5.92E+10	NR		
9/22/04		6.77	38.2%	345	5.71E+10	NR	**NR**	**NR**
7/20/04	Mid-Range Flows	3.63	57.5%	179	1.59E+10	NR		
8/11/04		3.49	58.5%	199	1.70E+10	NR		
10/1/04		3.24	60.7%	119	9.42E+09	NR		
10/4/04		2.94	63.6%	119	8.56E+09	NR		
8/17/04		2.84	64.4%	548	3.81E+10	NR		
10/8/04		2.62	66.7%	326	2.09E+10	NR		
8/26/04		2.31	69.4%	485	2.74E+10	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-38. Calculated Load Reduction Based on Geomean Data – Swanpond Creek

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	3.63	57.5%	179			
7/29/04	14.33	18.3%	411			
8/3/04	8.90	29.9%	272			
8/11/04	3.49	58.5%	199			
8/17/04	2.84	64.4%	548	293.62	57.1	61.5
8/26/04	2.31	69.4%	485	358.39	**64.8**	**68.5**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-39. Calculated Load Reduction Based on Daily Loading – Flat Creek

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
6/22/04	High Flows	200.64	2.1%	228	1.12E+12	NR		
6/28/04		58.39	9.7%	461	6.59E+11	NR	**NR**	**NR**
7/7/04	Moist Conditions	32.51	18.1%	770	6.12E+11	NR		
8/3/04		24.95	24.1%	727	4.44E+11	NR		
7/1/04		21.79	27.8%	435	2.32E+11	NR	**NR**	**NR**
9/23/04	Mid-Range Flows	13.50	40.1%	387	1.28E+11	NR		
7/14/04		10.74	47.0%	1046	2.75E+11	**10.0**		
9/29/04		8.39	53.7%	135	2.77E+10	NR		
7/20/04		8.31	54.0%	435	8.84E+10	NR		
7/22/04		7.56	56.6%	313	5.79E+10	NR		
8/16/04		6.85	59.4%	727	1.22E+11	NR	**1.7**	**3.2**
9/2/04	Low Flows	4.36	70.6%	365	3.89E+10	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-40. Calculated Load Reduction Based on Geomean Data – Flat Creek

Sample Date	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Geometric Mean [CFU/100 ml]	Calculated Reduction to Target GM (126 CFU/100 ml) [%]	Calculated Reduction to Target – MOS (113 CFU/100 ml) [%]
6/22/04	200.64	2.1%	228			
6/28/04	58.39	9.7%	461			
7/1/04	21.79	27.8%	435			
7/7/04	32.51	18.1%	770			
7/14/04	10.74	47.0%	1046	516.69	75.6	78.1
7/20/04	8.31	54.0%	435	502.08	74.9	77.5
7/22/04	7.56	56.6%	313	529.31	76.2	78.7
8/3/04	24.95	24.1%	727	603.00	**79.1**	**81.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-41. Calculated Load Reduction Based on Daily Loading – Little Flat Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/11/05	High Flows	57.29	1.3%	172	2.41E+11	NR		
5/24/00		34.50	3.1%	2419	2.04E+12	**61.1**		
12/13/04		22.53	5.6%	461	2.54E+11	NR	**20.4**	**21.7**
2/3/05	Moist Conditions	10.79	14.3%	310	8.19E+10	NR		
4/12/05		9.99	16.0%	520	1.27E+11	NR		
5/4/05		8.32	19.4%	148	3.01E+10	NR		
6/2/05		6.39	25.9%	5290	8.27E+11	**82.2**		
11/9/04		4.51	35.2%	310	3.42E+10	NR	**16.4**	**16.8**
3/3/05	Mid-Range Flows	3.36	43.1%	100	8.23E+09	NR		
2/24/00		2.22	54.3%	50	2.72E+09	NR		
8/24/00		2.19	54.7%	2419	1.30E+11	**61.1**	**20.4**	**21.7**
7/21/04	Low Flows	1.07	72.1%	108	2.81E+09	NR		
10/5/04		0.92	75.1%	291	6.58E+09	NR		
8/11/04		0.87	76.2%	214	4.54E+09	NR		
9/1/04		0.49	88.2%	299	3.57E+09	NR		
11/2/00		0.21	99.3%	44	2.28E+08	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-42. Calculated Load Reduction Based on Daily Loading – Roseberry Creek

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/26/04	High Flows	71.08	4.4%	727	1.26E+12	NR	**NR**	**NR**
7/29/04	Moist Conditions	20.23	16.7%	548	2.71E+11	NR		
6/29/04		16.70	20.8%	365	1.49E+11	NR		
8/3/04		12.51	27.8%	291	8.91E+10	NR		
9/22/04		9.36	35.5%	548	1.26E+11	NR	**NR**	**NR**
7/20/04	Mid-Range Flows	4.98	54.6%	276	3.36E+10	NR		
8/11/04		4.79	55.8%	330	3.87E+10	NR		
10/1/04		4.41	58.4%	517	5.58E+10	NR		
8/17/04		3.89	62.2%	1300	1.24E+11	**27.6**		
10/7/04		3.67	63.9%	285	2.56E+10	NR	**5.5**	**7.0**

Note: NR = No reduction required
NA = Not applicable

Table E-43. Calculated Load Reduction Based on Geomean Data – Roseberry Creek

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
7/20/04	4.98	54.6%	276			
7/29/04	20.23	16.7%	548			
8/3/04	12.51	27.8%	291			
8/11/04	4.79	55.8%	330			
8/17/04	3.89	62.2%	1300	452.07	**72.1**	**75.0**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-44 Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

Waterbody Description **(TN05130205__)**	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs[c]	CS	Industrial NPDES	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
Alexander Creek Waterbody ID: **011 – 0850** HUC-12: 0101	High Flows	0 – 10	24.44 – 349.0	40.74	15.0	9.370×10^{11}	9.370×10^{10}	NA	0	NA	1.666×10^{8}	1.666×10^{8}
	Moist	10 – 40	6.46 – 24.44	11.05	16.0	2.542×10^{11}	2.542×10^{10}				4.519×10^{7}	4.519×10^{7}
	Mid-Range	40 – 70	2.71 – 6.46	4.17	NR	9.591×10^{10}	9.591×10^{9}				1.705×10^{7}	1.705×10^{7}
	Low Flows	70 – 100	1.33 – 2.71	1.94	22.5	4.462×10^{10}	4.462×10^{9}				7.933×10^{6}	7.933×10^{6}
Hord Creek Waterbody ID: **011 – 0700** HUC-12: 0101	High Flows	0 – 10	16.83 – 254.2	29.16	6.9	6.707×10^{11}	6.707×10^{10}	NA	NA	NA	1.635×10^{8}	1.635×10^{8}
	Moist	10 – 40	3.97 – 16.83	7.33	NR	1.686×10^{11}	1.686×10^{10}				4.110×10^{7}	4.110×10^{7}
	Mid-Range	40 – 70	1.14 – 3.97	2.22	NR	5.106×10^{10}	5.106×10^{9}				1.245×10^{7}	1.245×10^{7}
	Low Flows	70 – 100	0.24 – 1.14	0.62	NR	1.426×10^{10}	1.426×10^{9}				3.476×10^{6}	3.476×10^{6}
Smith Creek Waterbody ID: **011 – 0900** HUC-12: 0101	High Flows	0 – 10	6.12 – 181.6	10.17	16.3	2.339×10^{11}	2.339×10^{10}	NA	0	NA	1.106×10^{8}	1.106×10^{8}
	Moist	10 – 40	1.68 – 6.12	2.77	NR	6.371×10^{10}	6.371×10^{9}				3.013×10^{7}	3.013×10^{7}
	Mid-Range	40 – 70	0.64 – 1.68	1.09	3.6	2.507×10^{10}	2.507×10^{9}				1.186×10^{7}	1.186×10^{7}
	Low Flows	70 – 100	0.11 – 0.64	0.32	NA	7.360×10^{9}	7.360×10^{8}				3.481×10^{6}	3.481×10^{6}
Bradley Creek Waterbody ID: **011 – 0500** HUC-12: 0102	High Flows	0 – 10	34.17 – 506.6	57.17	48.5	1.315×10^{12}	1.315×10^{11}	NA	NA	NA	1.622×10^{8}	1.622×10^{8}
	Moist	10 – 40	7.85 – 34.17	14.53	49.2	3.342×10^{11}	3.342×10^{10}				4.121×10^{7}	4.121×10^{7}
	Mid-Range	40 – 70	2.49 – 7.85	4.58	18.8	1.053×10^{11}	1.053×10^{10}				1.299×10^{7}	1.299×10^{7}
	Low Flows	70 – 100	0.48 – 2.49	1.35	46.2	3.105×10^{10}	3.105×10^{9}				3.829×10^{6}	3.829×10^{6}
Forgey Creek Waterbody ID: **011 – 0200** HUC-12: 0102	High Flows	0 – 10	13.54 – 202.8	22.98	20.4	5.285×10^{11}	5.285×10^{10}	1.500×10^{9}	0	NA	1.621×10^{8}	1.621×10^{8}
	Moist	10 – 40	3.18 – 13.54	5.84	4.3	1.343×10^{11}	1.343×10^{10}				4.082×10^{7}	4.082×10^{7}
	Mid-Range	40 – 70	0.98 – 3.18	1.81	NR	4.163×10^{10}	4.163×10^{9}				1.230×10^{7}	1.230×10^{7}
	Low Flows	70 – 100	0.19 – 0.98	0.54	51.5	1.242×10^{10}	1.242×10^{9}				3.309×10^{6}	3.309×10^{6}
Hunt Creek Waterbody ID: **011 – 1600** HUC-12: 0102	High Flows	0 – 10	8.70 – 187.6	14.89	11.2	3.425×10^{11}	3.425×10^{10}	NA	NA	NA	1.417×10^{8}	1.417×10^{8}
	Moist	10 – 40	2.15 – 8.70	3.85	15.5	8.855×10^{10}	8.855×10^{9}				3.665×10^{7}	3.665×10^{7}
	Mid-Range	40 – 70	0.66 – 2.15	1.25	2.8	2.875×10^{10}	2.875×10^{9}				1.190×10^{7}	1.190×10^{7}
	Low Flows	70 – 100	0.14 – 0.66	0.36	16.7	8.280×10^{9}	8.280×10^{8}				3.427×10^{6}	3.427×10^{6}
Renfroe Creek Waterbody ID: **011 – 0510** HUC-12: 0102	High Flows	0 – 10	15.42 – 232.9	26.24	13.7	6.035×10^{11}	6.035×10^{10}	NA	NA	NA	1.616×10^{8}	1.616×10^{8}
	Moist	10 – 40	3.58 – 15.42	6.62	32.7	1.523×10^{11}	1.523×10^{10}				4.078×10^{7}	4.078×10^{7}
	Mid-Range	40 – 70	1.05 – 3.58	2.02	NR	4.646×10^{10}	4.646×10^{9}				1.244×10^{7}	1.244×10^{7}
	Low Flows	70 – 100	0.22 – 1.05	0.57	26.6	1.311×10^{10}	1.311×10^{9}				3.511×10^{6}	3.511×10^{6}
Sinking Creek Waterbody ID: **011 – 0100** HUC-12: 0102	High Flows	0 – 10	4.27 – 64.3	7.20	20.4	1.656×10^{11}	1.656×10^{10}	NA	NA	NA	1.626×10^{8}	1.626×10^{8}
	Moist	10 – 40	0.99 – 4.27	1.83	0.8	4.209×10^{10}	4.209×10^{9}				4.133×10^{7}	4.133×10^{7}
	Mid-Range	40 – 70	0.31 – 0.99	0.57	40.4	1.311×10^{10}	1.311×10^{9}				1.287×10^{7}	1.287×10^{7}
	Low Flows	70 – 100	0.06 – 0.31	0.17	40.7	3.910×10^{9}	3.910×10^{8}				3.840×10^{6}	3.840×10^{6}

Table E-44 (cont'd) Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

Waterbody Description (TN05130205__)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs [c]	CS	Industrial NPDES	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
Stoney Pt Creek	High Flows	0 – 10	18.04 – 266.0	30.00	20.4	6.900×10^{11}	4.375×10^{10}	NA	NA	NA	1.625×10^{8}	1.625×10^{8}
Waterbody ID:	Moist	10 – 40	4.17 – 18.04	7.65	7.9	1.760×10^{11}	1.760×10^{10}				4.143×10^{7}	4.143×10^{7}
011 – 0400	Mid-Range	40 – 70	1.36 – 4.17	2.44	NR	5.612×10^{10}	5.612×10^{9}				1.321×10^{7}	1.321×10^{7}
HUC-12: 0102	Low Flows	70 – 100	0.25 – 1.36	0.72	15.3	1.656×10^{10}	1.656×10^{9}				3.899×10^{6}	3.899×10^{6}
Surgoinsville Creek	High Flows	0 – 10	13.25 – 196.3	22.02	31.6	5.065×10^{11}	5.065×10^{10}	NA	NA	NA	1.614×10^{8}	1.614×10^{8}
	Moist	10 – 40	3.05 – 13.25	5.61	NR	1.290×10^{11}	1.290×10^{10}				4.113×10^{7}	4.113×10^{7}
Waterbody ID:	Mid-Range	40 – 70	0.95 – 3.05	1.75	NR	4.025×10^{10}	4.025×10^{9}				1.283×10^{7}	1.283×10^{7}
011 – 0300 HUC-12: 0102	Low Flows	70 – 100	0.18 – 0.95	0.52	13.2	1.196×10^{10}	1.196×10^{9}				3.813×10^{6}	3.813×10^{6}
Stanley Creek	High Flows	0 – 10	19.34 – 289.5	33.85	NR	7.786×10^{11}	7.786×10^{10}	NA	NA	NA	8.287×10^{7}	8.287×10^{7}
Waterbody ID:	Moist	10 – 40	4.52 – 19.34	8.43	NR	1.939×10^{11}	1.939×10^{10}				2.064×10^{7}	2.064×10^{7}
015 – 0300	Mid-Range	40 – 70	1.34 – 4.52	2.55	NR	5.865×10^{10}	5.865×10^{9}				6.243×10^{6}	6.243×10^{6}
HUC-12: 0103	Low Flows	70 – 100	0.28 – 1.34	0.73	19.3	1.679×10^{10}	1.679×10^{9}				1.787×10^{6}	1.787×10^{6}
Crockett Creek	High Flows	0 – 10	14.65 – 211.8	24.36	20.4	5.603×10^{11}	5.603×10^{10}	NA	0	NA	1.709×10^{8}	1.709×10^{8}
Waterbody ID:	Moist	10 – 40	3.77 – 14.65	6.57	16.4	1.511×10^{11}	1.511×10^{10}				4.608×10^{7}	4.608×10^{7}
004T – 1200	Mid-Range	40 – 70	1.16 – 3.77	2.17	20.4	4.991×10^{10}	4.991×10^{9}				1.522×10^{7}	1.522×10^{7}
HUC-12: 0201	Low Flows	70 – 100	0.18 – 1.16	0.56	NR	1.288×10^{10}	1.288×10^{9}				3.928×10^{6}	3.928×10^{6}
Caney Creek	High Flows	0 – 10	27.36 – 574.0	46.50	NR	1.070×10^{12}	1.070×10^{11}	NA	NA	NA	1.432×10^{8}	1.432×10^{8}
Waterbody ID:	Moist	10 – 40	6.62 – 27.36	11.88	10.4	2.732×10^{11}	2.732×10^{10}				3.658×10^{7}	3.658×10^{7}
004T – 1150	Mid-Range	40 – 70	2.03 – 6.62	3.88	14.9	8.924×10^{10}	8.924×10^{9}				1.195×10^{7}	1.195×10^{7}
HUC-12: 0204	Low Flows	70 – 100	0.43 – 2.03	1.09	13.1	2.507×10^{10}	2.507×10^{9}				3.356×10^{6}	3.356×10^{6}
Turkey Creek	High Flows	0 – 10	18.02 – 337.8	30.52	94.4	7.020×10^{11}	7.020×10^{10}	NA	0	$3.97 \times 10^{9} \times Q_2$	1.999×10^{8}	1.999×10^{8}
Waterbody ID:	Moist	10 – 40	3.93 – 18.02	7.21		1.658×10^{11}	1.658×10^{10}				4.721×10^{7}	4.721×10^{7}
004T – 2100	Mid-Range	40 – 70	1.18 – 3.93	2.22		5.106×10^{10}	5.106×10^{9}				1.454×10^{7}	1.454×10^{7}
HUC-12: 0207	Low Flows	70 – 100	0.21 – 1.18	0.53		1.219×10^{10}	1.219×10^{9}				3.471×10^{6}	3.471×10^{6}
Mossy Creek	High Flows	0 – 10	29.09 – 673.3	51.94	80.9	1.195×10^{12}	1.195×10^{11}	NA	0	NA	NA	1.625×10^{8}
Waterbody ID:	Moist	10 – 40	7.18 – 29.09	12.64		2.907×10^{11}	2.907×10^{10}					3.956×10^{7}
004T – 2400	Mid-Range	40 – 70	2.55 – 7.18	4.44		1.021×10^{11}	1.021×10^{10}					1.389×10^{7}
HUC-12: 0210	Low Flows	70 – 100	0.50 – 2.55	1.22		2.806×10^{10}	2.806×10^{9}					3.818×10^{6}
Beaver Creek	High Flows	0 – 10	56.31 – 1607.7	109.23	85.7	2.512×10^{12}	2.512×10^{11}	NA	NA	NA	NA	1.740×10^{8}
Waterbody ID:	Moist	10 – 40	14.29 – 56.31	24.92		5.732×10^{11}	5.732×10^{10}					3.970×10^{7}
001 – 0900	Mid-Range	40 – 70	4.86 – 14.29	8.11		1.865×10^{11}	1.865×10^{10}					1.292×10^{7}
HUC-12: 0302	Low Flows	70 – 100	1.10 – 4.86	2.60		5.980×10^{10}	5.980×10^{9}					4.142×10^{6}

Table E-44 (cont'd) Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Holston River Watershed (HUC 06010104)

Waterbody Description (TN05130205__)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs [c]	CS	Industrial NPDES	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]		[CFU/d/ac]
Lost Creek	High Flows	0 – 10	48.04 – 1123.4	85.28	92.2	1.961×10^{12}	1.961×10^{11}	NA	NA	NA	NA	1.586×10^{8}
Waterbody ID:	Moist	10 – 40	11.14 – 48.04	20.29		4.667×10^{11}	4.667×10^{10}					3.774×10^{7}
001 – 0800	Mid-Range	40 – 70	4.02 – 11.14	6.91		1.589×10^{11}	1.589×10^{10}					1.285×10^{7}
HUC-12: 0302	Low Flows	70 – 100	0.86 – 4.02	2.01		4.623×10^{10}	4.623×10^{9}					3.738×10^{6}
Richland Creek	High Flows	0 – 10	146.84 – 4157.7	281.61	79.6	6.477×10^{12}	6.477×10^{11}	7.400×10^{9}	0	NA	NA	1.478×10^{8}
Waterbody ID:	Moist	10 – 40	37.06 – 146.84	63.86		1.469×10^{12}	1.469×10^{11}					3.336×10^{7}
018 – 1000	Mid-Range	40 – 70	12.37 – 37.06	22.15		5.095×10^{11}	5.095×10^{10}					1.145×10^{7}
HUC-12: 0303	Low Flows	70 – 100	2.96 – 12.37	6.38		1.467×10^{11}	1.467×10^{10}					3.164×10^{6}
Swanpond Creek	High Flows	0 – 10	24.53 – 738.58	47.06	64.8	1.082×10^{12}	1.082×10^{11}	NA	0	NA	1.510×10^{8}	1.510×10^{8}
Waterbody ID:	Moist	10 – 40	6.34 – 24.53	10.83		2.491×10^{12}	2.491×10^{11}				3.474×10^{7}	3.474×10^{7}
001 – 1400	Mid-Range	40 – 70	2.26 – 6.34	3.96		9.108×10^{11}	9.108×10^{10}				1.270×10^{7}	1.270×10^{7}
HUC-12: 0304	Low Flows	70 – 100	0.46 – 2.26	1.11		2.553×10^{11}	2.553×10^{10}				3.561×10^{6}	3.561×10^{6}
Flat Creek	High Flows	0 – 10	57.37 – 1411.0	103.45	79.1	2.379×10^{12}	2.379×10^{11}	NA	NA	NA	1.516×10^{8}	1.516×10^{8}
Waterbody ID:	Moist	10 – 40	13.55 – 57.37	23.89		5.495×10^{11}	5.495×10^{10}				3.500×10^{7}	3.500×10^{7}
019 – 2000	Mid-Range	40 – 70	4.50 – 13.55	7.98		1.835×10^{11}	1.835×10^{10}				1.169×10^{7}	1.169×10^{7}
HUC-12: 0305	Low Flows	70 – 100	1.10 – 4.50	2.35		5.405×10^{10}	5.405×10^{9}				3.443×10^{6}	3.443×10^{6}
Little Flat Creek	High Flows	0 – 10	45.56 – 1362.6	86.80	20.4	1.996×10^{12}	1.996×10^{11}	NA	NA	NA	NA	1.441×10^{8}
Waterbody ID:	Moist	10 – 40	11.19 – 45.56	19.63	16.4	4.515×10^{11}	4.515×10^{10}					3.259×10^{7}
019 – 0100	Mid-Range	40 – 70	3.65 – 11.19	6.46	20.4	1.486×10^{11}	1.485×10^{10}					1.072×10^{7}
HUC-12: 0305	Low Flows	70 – 100	0.18 – 3.65	1.94	NR	4.462×10^{10}	4.462×10^{9}					3.220×10^{6}
Roseberry Creek	High Flows	0 – 10	31.54 – 950.7	61.85	72.1	1.423×10^{12}	1.423×10^{11}	NA	0	NA	1.514×10^{8}	1.514×10^{8}
Waterbody ID:	Moist	10 – 40	8.03 – 31.54	14.14		3.252×10^{11}	3.252×10^{10}				3.462×10^{7}	3.462×10^{7}
001 – 0500	Mid-Range	40 – 70	2.90 – 8.03	4.91		1.129×10^{11}	1.129×10^{10}				1.202×10^{7}	1.202×10^{7}
HUC-12: 0306	Low Flows	70 – 100	0.63 – 2.90	1.45		3.335×10^{10}	3.335×10^{9}				3.550×10^{6}	3.550×10^{6}

Notes: NA = Not Applicable.
NR = No Reduction Required.
PLRG = Percent Load Reduction Goal to achieve TMDL.
CS = Collection Systems
Q_2 = Mean Daily Flow (cfs) from Permitted Industrial Point Source.
Shaded Flow Zone for each waterbody represents the critical flow zone.

a. Flow applied to TMDL, MOS, and allocation (WLA[MS4] and LA) calculations. Flows represent the midpoint value in the respective hydrologic flow regime.
b. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.

APPENDIX F

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN HOLSTON RIVER WATERSHED (HUC 06010104), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Holston River watershed, located in eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies in the Holston River watershed are listed on Tennessee's Final 2008 303(d) list as not supporting designated use classifications due, in part, to pasture grazing and collection system failure. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of pathogen loading on the order of 3-94% in the listed waterbodies.

Holston River E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Vicki S. Steed, P.E., Watershed Management Section
Telephone: 615-532-0707

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than August 18, 2008 to:

Division of Water Pollution Control
Watershed Management Section
7th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.